ISTVS

International
Society for
Terrain-
Vehicle
Systems

4th EUROPEAN CONFERENCE

Wageningen, The Netherlands

21-23rd March, 1989

PROCEEDINGS
VOLUME 2

IMAG

4th EUROPEAN CONFERENCE

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PROCEEDINGS
VOLUME 2

THEME
"Terrain-Vehicle Systems and Sustained Soil Quality"

These Proceedings are published in two volumes by the Organizing Committee of the 4th European Conference of the International Society for Terrain-Vehicle Systems

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OPENING

Brig.Gen. S.A.K. Areskoug
ISTVS Dep. General Secretary for Europe

Ladies and Gentlemen,

It is a great pleasure for me as ISTVS Deputy General Secretary for Europe to meet so many old friends and a lot of new ones at this, the 4th European ISTVS Conference.

The idea of arranging European Conferences first came up at the 6th Int. Conf. in Vienna 1978. Two years later the first European Conf. was held in Rottach-Egern near Munich in Germany in cooperation with the Tech. Univ. of Munich, the Battelle Institute Frankfurt and the MAN company.

The intention was that we should not compete with the "state-of-the-art" International Conferences, but instead aim at active exchange of experiences and not least at promoting personal contacts. A choice of limited topics and much time for group discussions were means for achieving this.

The first Europe Conference had the topics Limits in the design of

- Agricultural Machinery
- Forestry Equipment
- Eartmoving Equipment and Influence of Mission Profile on Off-Road Machinery Design

The second conference in Ferrara aimed at overbridging the gap between Land-Locomotion theories and applictions.

The third in Warsaw was for linguistic reasons more conventional and treated "Off-Road machinery in agriculture, earthwork and forestry".

Here in Wageningen we all know the topics of the sessions.

I am very grateful to the Dutch Institute of Agricultural Engineering, who has undertaken to arrange and host this conference. The devoted preparations made by the Organizing Committee are our guarantee for three interesting and valuable days.

In the programme you have noticed that there is plenty of time for workshops. With Lord Nelson in mind I would say: **"ISTVS expects every attendee to do his duty"**

The future looks very positive. We have a lot of preliminar offers to host coming conferences, which we will discuss at the Board o Directors meeting to night. At the concluding session on Thursday we will tell you of coming events.

Ladies and Gentlemen,

I declare the 4th European ISTVS

Conference opened

FIRST EUROPEAN CONFERENCE
ON TERRAIN-VEHICLE SYSTEMS

25-27 MARCH 1980

ROTTACH-EGERN, GERMANY

The International Society for

Terrain-Vehicle Systems

2ND EUROPEAN CONFERENCE
2ª CONFERENZA EUROPEA

OFF-ROAD TRANSPORTATION AND SOIL WORKING:
MEANS TO PROMOTE DEVELOPMENT AND OPERATIONS

LOCOMOZIONE FUORI STRADA E LAVORAZIONE DEL TERRENO:
VOLTA A PROMUOVERE LO SVILUPPO E L'OPERATIVITA'

3-4-5 OCTOBER 1983
FERRARA ITALY

Third European Conference

OFF THE ROAD VEHICLES AND MACHINERY
IN AGRICULTURE, EARTHWORK
AND FORESTRY

15 – 17 September 1986

WARSAW – POLAND

ISTVS

4th EUROPEAN CONFERENCE

IAC CONFERENCE CENTRE

WAGENINGEN, THE NETHERLANDS

21 - 23 March 1989

INTRODUCTORY REMARKS

R.D. WISMER (President of ISTVS)

You are all part of what I believe will be an exiting 4 th European Conference of ISTVS "Terrain-Vehicle Systems and Sustained Soil Quality ". We are indebted to IMAG for organising and hosting the conference.

ISTVS is a society of 352 specialist that are concerned with enhancing and predictability of terrain-vehicle systems.
This includes:
- vehicle
- soil-traction
- soil-machine-crop
- terrain-vehicle dynamics
- system modelling.

The industries represented among our membership include:
- agricultural machines
- military vehicles
- forestry vehicles
- mining / exploration vehicles
- construction machines
- aerospace / extra terrestrial terrain machines.

The Society sponsors an international conference every 3 year - the next the 10th international conference of ISTVS will be August 20-24 1990 in Kobe, Japan. We also sponsor a number of regional conferences for example the 2nd Asian-Pacific Conference, Bangkok Thailand 6-10 Dec 1988, this 4th European Conference, and the joint US-Canadian conference 25-27 April of this year.

I trust you will find this conference valuable and enjoyable. If you do and are not a memeber of ISTVS please consider joining. Information on ISTVS membership will be available later in the morning.

Have a good conference !

OPENING 4TH EUROPEAN ISTVS CONFERENCE

G.J.H RIJKENBARG (Interim Director of IMAG)

On behalf of the board of directors of the Institute of Agricultural Engineering at Wageningen I welcome you all, not only in our institute, but also in Wageningen, the centre of Agricultural Research and Education of the Netherlands.

The IMAG is honoured to be invited for organizing this 4th European Conference. The Organizing Comittee has done and will do their utmost to assure that the Conference will be a success and your stay in the Netherlands will be pleasant.

Tomorrow will be an excursion day and one topic of the tour is a short visit to our institute. Mr Perdok will be the host at the IMAG-location. At that occasion he will introduce our institute to you.

Tomorrow evening at the conference-dinner I hope to seen you again.

I wish you all a fruitful, interesting and pleasant Conference and a happy stay in the Netherlands.

OPENING ADDRESS 4TH EUROPEAN ISTVS CONFERENCE

TERRAIN-VEHICLE SYSTEMS AND SUSTAINED SOIL QUALITY

U.D. PERDOK*

Introduction

Welcome to the fourth European ISTVS-conference. We gladly accepted the opportunity to host this regional conference. By now, many outstanding researchers in the field of land locomotion are together in the audience. You might help us, to solve some of our off-road problems in the Benelux.
On the other hand we may offer you some positive experiences gained in agricultural and military business. So we pursue and hope for mutual knowledge exchange, and general progress for our joint discipline of terra-mechanics.
As conference theme we have selected "Terrain-Vehicle systems and sustained soil quality".
Not astonishing, when you bear in mind the importance of agriculture in our country, the professional background of the committée-members and the fact that mechanized farming develops to be a threat for the soil quality of our soft "polder" soils. Many of our research projects are devoted therefore to field traffic, that can avoid soil degradation and crop yield reduction. No wonder that we like to point this conference to the machine-soil-plant system (Fig. 1).
Let me make some remarks as a general introduction to the theme.
The vehicle takes a key position in the figure and represents the denominator for our joint professional interest. Depending on the various applications, this vehicle may be an agricultural tractor, a lorry, a battle tank, a forwarder or what else have you ?
For our purpose the loads to be carried out and the wheel equipment used (being tyre or track) are the most relevant parts to be brought in the system.
The factor soil plays an important double role. In the first place mobility aspects in relation to vehicle performance are relevant. A limited soil-bearing capacity will often hamper vehicle efficiency !
In the second place, soil should offer a stand for plants and crops. In the Netherlands this aspect also plays a role nowadays on the military training areas. Most plants need a relatively loose and moist soil in order to be supplied with enough water, air and nutrients. The challenge is to match the contradicting requirements from a vehicle and plant oriented view. Going on, we come to the plant itself, which may be in the shape of a vegetation (nature reserve, grassland, training area) a forest in a permanent lay-out or in the shape of an annual crop for the market.
The conference theme adresses sustained soil quality. It may be clear that soil quality has a different meaning for the different disciplines assembled here. Military people may be only concerned with the mobility aspects (who cares about plants at war time ?). For training areas, however, their appears to be growing interest in the value of the vegetation for the preservation of nature. For agriculture and forestry, maintaining productive soil is essential.
Fig. 2 shows the factors that play a role in soil quality management for agriculture. Apart from the factor vehicle, a combination of climate (read: soil moisture), technology (read: tillage and other soil improvements) and management (read: time and type of operations) determines soil quality and thus plant production and even produce quality.

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Developments in traction and transport

Let me now go a little further in detail about developments in Dutch agriculture, up till to day and those of tomorrow. Due to our high population density,land use is very intensive from the past on. Each potential piece of land has been reclaimed; most times primarily for agricultural purposes. Next to land productivity also man productivity has been raised, thanks to mechanisation in stead of draught animals.
Since the fifties the tractor has become the most important power unit. As indicated in Fig. 3, tractors have become much more powerfull during the last decades (factor 3.5). By now, the drive line allows an easy adaptation to varying soil conditions, 4 w.d. and bigger front wheels is almost completely introduced on tractors over 60 kW. Convenience and safety have gained by low-noise cabs etc.
The latest development is, that micro-electronics are being introduced in the tractor board computer in order to accomplish a better linkage and implement control (Fig. 4).

Traction and transport are very important phenomena to the farmers, especially to the arable farmer. Roughly 60% of his fieldwork consists of transport activities.
So you may state that the farming business is synonymous to transport business. For productivity reasons, heavy farm trailers have been introduced. High wheel and axle loads cause a growing concern, also under farmers, for soil structure on the long run. It seems a "must" to further improve the wheel equipment by using low pressure tyres for instance; 10-15 years ago IMAG made already an attempt to improve the wheel equipment for a heavy container carrier (Fig. 5).

Looking back in general, we can trace the following trends in Research and Development (Fig. 6). In the sixties and early seventies ag. eng. research was fixed upon performance aspects, better principles and design for mouldboards, better tyres thanks to single wheel tester research and so on.
In the mid seventies the technical approach was widened, incorporating soil qualities as ploughing and rolling resistance.
Empirical models for tractor tool combinations could be described. Application is found in developed countries and also in developing countries, for the sake of tropical mechanisation, where soil dynamics data are often missing.
From the early eighties onwards soil qualities in relation to plant growth are studied more thoroughly.
Most recently system research has been started, aiming at better soil and crop management, of course to be carried out in teamwork.

Cropping systems research

Looking for better cropping systems, we may distinguish some possible options in relation to tillage and traffic.

In current practice a lot of energy is put into tillage and traffic during the production cycle. Soil loosening and compacting processes are always alternating ! The wheel acts like a natural opponent of the plough.
The question is how to jump out of this vicious circle.

In the no-till system you may skip the tillage, keep the traffic and still hope for a reasonable soil structure and weed control.
Pasture land in our country is treated that way !
But no-till is unsuitable for row crops in our country.

In case of arable farming and especially field production of vegetables the traffic may be controlled among others by concentrating all wheelings on permanent lanes. In between, the beds are freed from uncontrolled loading. We tested in detail a 3 m system. Coming April we will start to introduce the 12 m Dowler gantry on our experimental farm (Fig. 7).

In the meantime we continue our cooperate E.C. research project concerning reduction of traffic induced soil compaction by using low ground pressure vehicles. Evaluation of the results will help us to further explore and define the optimum soil conditions. We are realizing that in the end we have to impose restrictions on the total loads of the vehicles and trailers in this system.

Future developments

Bringing my speech to a close now, I like to ventilate a preview of our research efforts for tomorrows agriculture. High tech farming and even computer aided farming will provide new means for proper soil management.
Some of the advances made in automatic control of technical processes have already been mentioned for the tractor-tool combination. New sensors mounted on tractors and implements together with sensors to be installed in the field, will gather information on soil and crop condition (Fig. 8).
The power unit and the setting of the linked implements can then be controlled automatically in order to adapt f.i. tyre pressure to the varying soil condition. So, optimisation of soil condition, but also crop husbandry seems feasible in near future. It may be based on field and yield mapping, or with help of information picked up by the sensors on the go.
Of course, the tractor board computer can easily be connected to the farm computer. On his turn the farmers P.C. may have an online connection to the main frame containing large data bases for a custom made extension service: made to measure instead of ready-made.
The development towards abundant availability of information will generate a strong demand for decision support systems, approved expert systems and models in tillage, traffic and mechanisation. For this, there will be growing need for standardization and quantitative research results.
Indeed the conference theme was illustrated from an agricultural engineering point of view. Fortunately your contributions are not all that one sided. Different applications in Volume 1 are shown with respect to forestry and military. Together we will contribute the sound scientific modules, to complete the picture of complex Terrain-Vehicle Systems in relation to sustained soil quality. I wish the authors a good deal of succes during the presentation of their paper.
Moreover I make an appeal to all of you, to generate spirited discussions in the workshops and on behalf of the organizing comitee I hope that all participants will combine this business with pleasure during your stay in our country.

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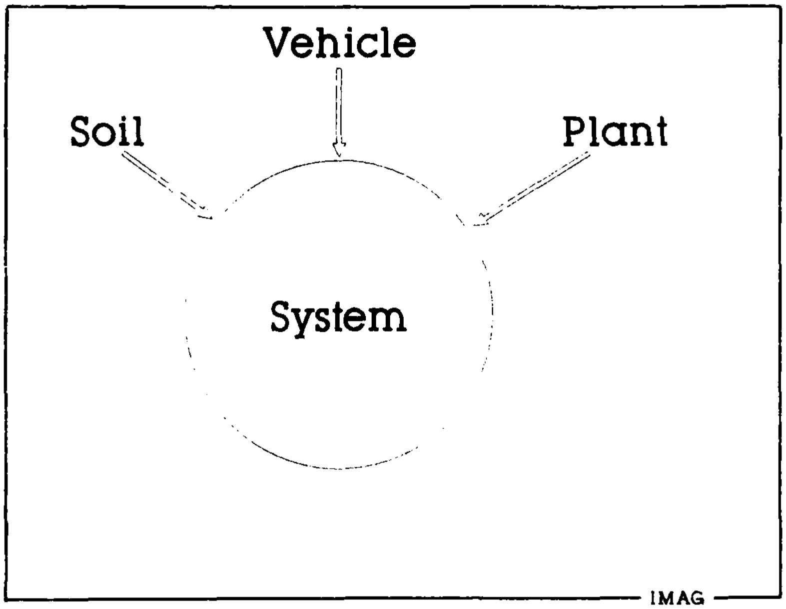

Fig. 1. The vehicle-soil-plant system.

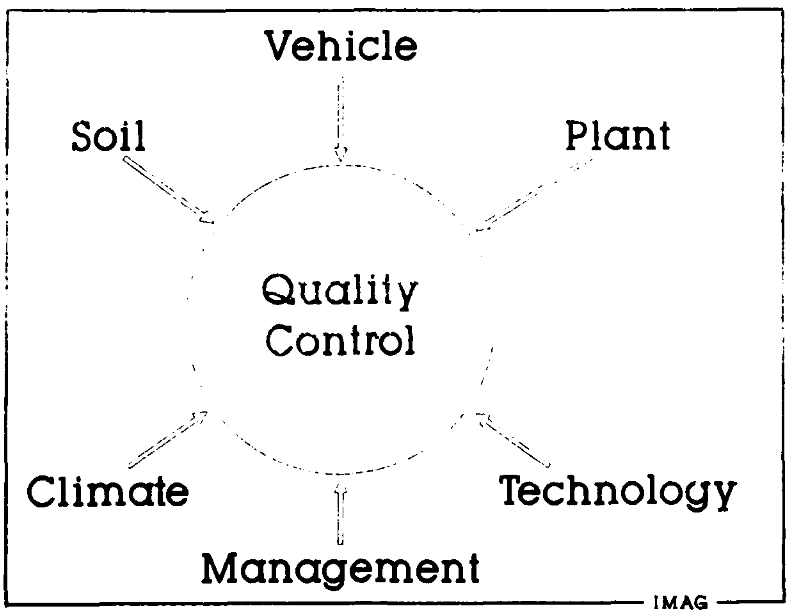

Fig. 2. Factors influencing soil quality control.

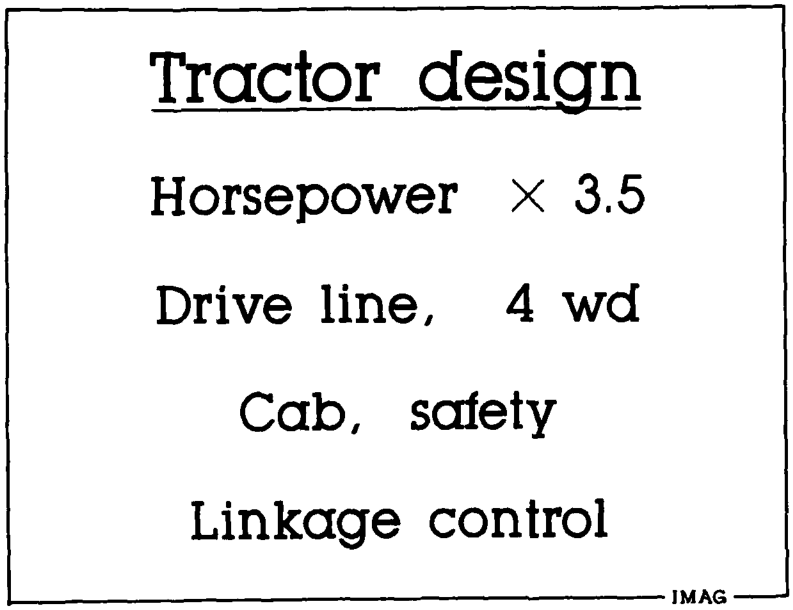

Fig. 3. The main developments in tractor design for the last decades.

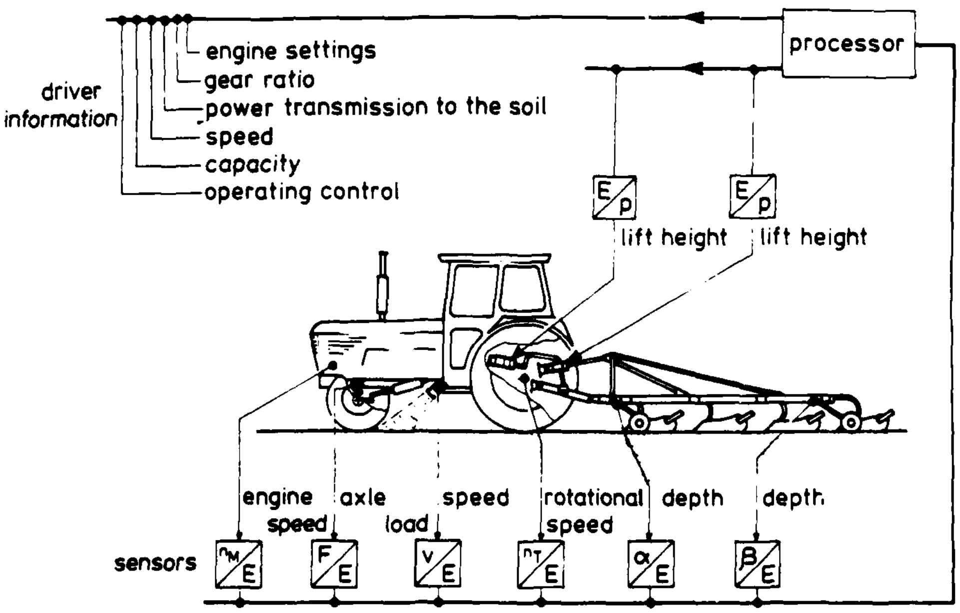

Fig. 4. A system to supply specific information to the tractor driver during soil tillage operations (Eimer and Dreses, 1985).

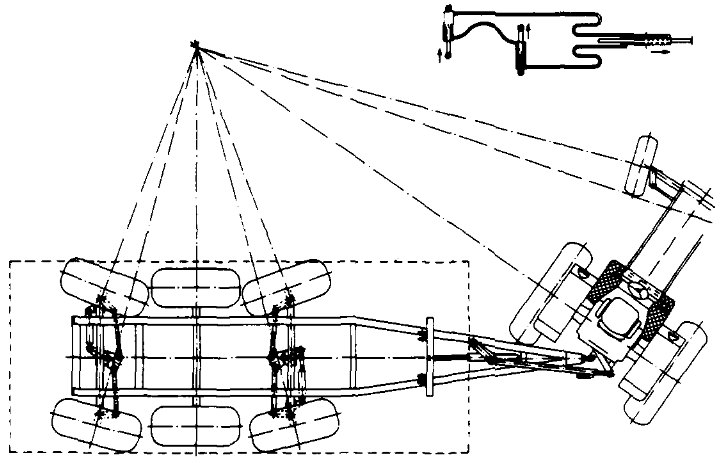

Fig. 5. IMAG 3-axle type container carrier with steered wheel configuration (Spaink and Van Maanen, 1978).

Trends in R + D

1960, performance

(principles)

1970, soil quality

(modelling)

1980, soil and crop management (systems)

1990,

IMAG

Fig. 6. Trends in Research and Development.

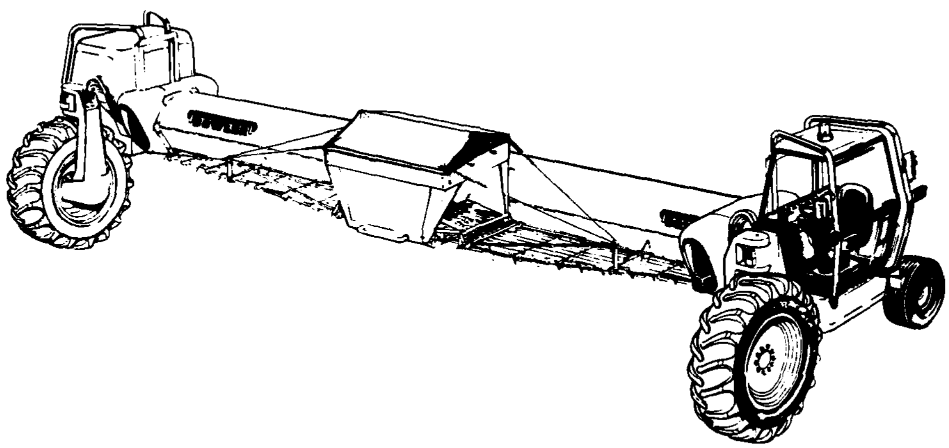

Fig. 7. The "Dowler" gantry.

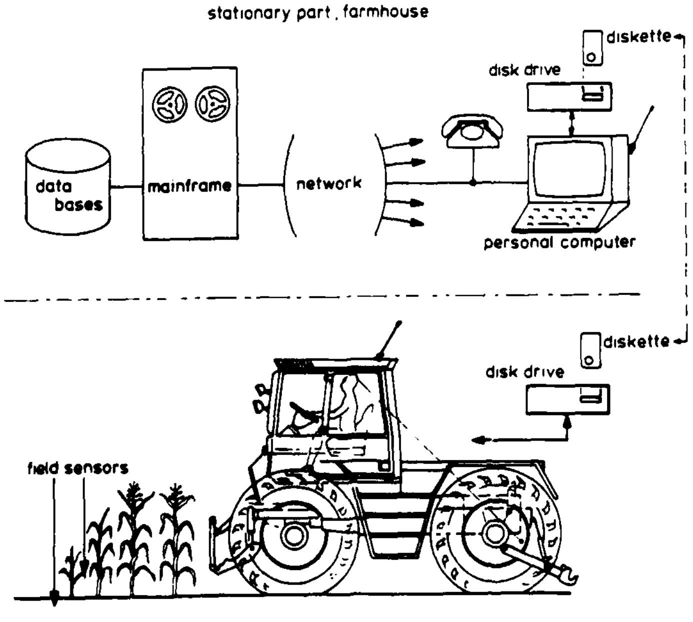

Fig. 8. A possible future Computer-Aided Farming (CAF) System (Mertins and Gerhards, 1986).

GENERAL REPORT SESSION I AND II

4TH EUROPEAN ISTVS CONFERENCE
Wageningen, The Netherlands
21-23rd March, 1989

SOIL-VEHICLE INTERACTION AND SUSTAINED SOIL QUALITY

F.G.J. TIJINK*

SUMMARY: Progress in soil-vehicle interaction in relation to sustained soil quality is reviewed. Topics covered include soil characteristics, traffic-induced soil stresses, wheel-soil-crop systems, forest site preparation and military training areas. Progress has been made in measuring characteristics relevant to agricultural, forestry and military fields of application. Generally acceptable methods should be evolved to describe and present soil characteristics and soil-vehicle interaction.

INTRODUCTION

The general theme of the 4th European ISTVS Conference, "Terrain-Vehicle Systems and Sustained Soil Quality" has been subdivided into 3 sessions:

Session I : Field Traffic and Soil Quality for Plant Growth.
Session II : Vehicle Systems and Soil Quality for Military Training Areas.
Session III : Advances in Mobility Devices and Soil-Vehicle Modelling.

The theme descriptions allow for a wide varity of papers. Inevitably there will be some overlap in the topics covered by the three sessions.

This report reviews progress in research on soil - vehicle interaction and sustained soil quality, as reflected in the papers submitted to Sessions I and II of the Conference. Both sessions have the word "soil quality" in their title. This can be explained in different ways for Session I (agriculture and forestry) and Session II (military, nature preservation and recreation).

Vehicle engineers generally restrict their interest in soil characteristics to characteristics relevant to vehicle performance. If the soil is a growing medium for plants (agriculture, forestry, multifunctional military training areas, etc.) the soil characteristics important to plant growth must be considered in addition to those of the soil's load supporting function. This complicates the vehicle-soil interaction. Fig. 1 shows these interrelations. The engineering input into the system comes from soil vehicle mechanics. The system input must be completed with relevant information from root bio-mechanics. Note that choosing and measuring relevant soil characteristics, both for soil behaviour under stess and for explaining plant performance, has a key position in vehicle-soil-plant research.

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The goal of Sessions I and II is to attract papers dealing with integrated research on soil-vehicle interaction and sustained soil quality. The papers can be roughly divided into 5 catagories:

"Soil characteristics"	7 papers [4,7,8,10,11,13,15]
Traffic-induced soil stresses	4 papers [1,5,9,12]
Wheel-soil-crop systems	2 papers [3,14]
Military training areas	2 papers [2,16]
Forest site preparation	1 paper [6]

About a quarter of the papers threats the system shown in Fig. 1. Almost half of the papers pays only attention to a part of the system: the characterization of soil condition and soil behaviour under stress.

Better knowledge of soil-vehicle interaction and soil quality is required to improve the design, control and use of vehicles , to sustain soil quality and model vehicle-soil-plant systems.

"SOIL CHARACTERISTICS"

The definition of the condition and the behaviour of topsoils is complex and sometimes contentious. However, choosing the right soil characteristics is very important.

Two groups of soil characteristics can be distinguished (see Fig. 2).

Permanent soil characteristics are often the basis of soil classification systems. In terramechanics the permanent characteristics are considered to be those that do not change significantly under all conditions encountered in off-road locomotion. In this context characteristics such as particle size, particle shape, specific gravity, and mineral composition can be considered as permanent. These characteristics are not influenced by the in situ soil condition.

Transient soil characteristics describe the actual state of soil. These characteristics can change as a result of environment and external load. They can be devided in:

- **volume/weight characteristics** such as porosity, void ratio, bulk density, moisture content, air content, and degree of saturation.
- **soil mechanical properties**. A subdivision can be made in:
  - **basic soil mechanical properties**. Characteristics such as cohesion, internal angle of friction, yield strength and elastic modulus can be considered as basic.
  - **empirical soil mechanical properties** such as cone (penetrometer) index and n and k of plate sinkage.
- **transport characteristics**. Permeability, diffusion characteristics for liquid and gas fractions, and soil water matrix potential are some examples of transport characteristics.

Soil disturbance induced by passing over with a vehicle is generally expressed as change in soil condition, characterized by initial and final state.

Characterization of the process itself (soil behaviour due to stress) is more complex because the state of stress and strain and the basic soil mechanical properties vary continuously during the passing of a running gear. This makes it very difficult to relate the processes to basic mechanical properties. Research workers therefore often use measuring devices to induce simpler but

comparable processes, as a method of characterization, yielding empirical soil mechanical properties and stress-strain analogies.
Several tests are available to characterize soil behaviour in this way: tri-axial test, uniaxial compression test, unconfined compression test, oedometer test, proctor test, cone penetration test, plate sinkage test, etc. Each field of application has its favorite test(s). The relationships between the different tests are hardly known.
As reflected in the conference papers, cone penetration [2,3,7,8,10,13,14] and plate sinkage [4,10,13] are the most popular methods of characterization. Note that the cone penetrometer and the plate penetration produce the same end result, i.e. empirical soil parameters such as CI (cone index), and n and k.

HADAS et al.[7] correlated cone penetration values with soil bulk density values (determined from core samples from the field). Empirical relationships were found (see e.g. Fig. 3). These relationships were then used to predict bulk density values in profiles of the same soil at different times after tilling the soil. The predicted bulk density values were compared with values from field core sampling. Accuracy of prediction improved when the soil was in a settled condition. The variability increased as root systems developed.

SITKEI [13] analysed the theoretical relationships between cone index and the factor k of plate sinkage. Two situations are distinguished in cone approach: the sliding state and the non-sliding state. In the sliding state the soil slides on the cone surface. High correlations were found between cone index and k factor determined in the upper 15.2 cm of forest soils. It must be pointed out that this could have been expected, because a penetrating plate can be seen as a cone with a different base area, penetration speed, tip angle (*a tip of* soil will be built up in front *of a* plate) and soil-cone friction.
The sliding state approach of the cone penetrometer gave the more reliable results.
A probability distribution of k-values was obtained by combining measured k-values with rainfall distributions (see Fig. 4).

WÄSTERLUND [15] developed a test rig to measure soil strength in forest soils. The rootmat is one of the special aspects of a forest soil. Ordinary equipment (shear ring) gave problems in determining strength properties. A segment of a slipping rigid wheel was adopted as testing instrument. The principle of the test rig and its first test runs are described.

PARRINGER [10] developed a method for continuously measuring several soil characteristics during field traffic. For this, a large agricultural tractor was equipped with the following measuring devices:

- a wheel test device to measure load-sinkage relationships
- a tine to measure cutting force
- a sled to measure cohesion and friction angle of the soil surface
- a set of wheels to measure tractor sinkage
- a transducer to indicate tyre deflection
- a three-wheel set to measure terrain surface roughness

The layout of the test device and some test results are briefly described. The continuous measuring of the traffic conditions needs to be developed further, to encourage the development of systems that provide specific information for the vehicle driver.

LERINK [8] measured several soil characteristics that may be important in relation to traffic systems and crop responses. Directly after a traffic system had passed, field core samples were taken in the centre of the rut and just beside the wheel rut. Each sample from a rut was subjected to the following measurements:

- moisture content and porosity directly after compaction
- moisture content, air content, air permeability, and penetrometer resistance (all after equilibrium at pF2)
- saturated water conductivity
- tensile strength (Brazilian test) after oven drying.

The samples from the no-traffic zone were compacted to 0.2 MPa in a uniaxial compression test.
Measured values are presented in "vehicle-soil diagrams" (Fig. 5).
An approach that uses these measurements in a comparative method for predicting the immediate effects of certain field traffic systems on field soil qualities is presented. The domain of the prediction method was restricted to two field traffic systems and the direct effects on one field.

GRAHN [4] considers the influence of the vertical penetration velocity in Bekker's analogy between a rolling rigid wheel and a penetration plate. Several penetration tests are presented. The soil condition was the same in all the penetration tests. The largest plate size used was 900 cm^2. This is comparable with the contact area of a wheel. Penetration velocities of up to 80 cm/s were used. A dimensionless relationship between the influence of pressure and penetration speed was derived (Fig. 6):

$$p_2/p_1=(z_2/z_1)^m$$

where, p=pressure and z=plate penetration velocity.
The pressure-sinkage relationship was transferred to a rigid wheel, resulting in a dynamic vertical pressure distribution for different forward speeds.

SCHWANGHART [11] measured tyre-induced soil compactions in a soil bin. One tyre was used in several combinations of wheel load and inflation pressure. Measured characteristics were: tyre sinkage and soil density at several depths. Two soil conditions were used: one homogeneous layer (Fig. 7a) and a loose layer above a firm layer (Fig. 7b). Attempts were made to calculate density distributions by using a void ratio-vertical pressure relation and Söhne's pressure distribution approach. It must be noted that a void ratio - pressure relation found in a uniaxial compression test cannot be directly translated to a tyre. Corrections have to be made for aspects of the tyre such as: flexibility (including tyre inflation pressure), unequal pressure distribution in the contact area, and shear stress in the contact area.

TRAFFIC-INDUCED SOIL STRESSES

The directions and magnitude of stress in soil are important when predicting the soil behaviour with the help of stress-strain analogies. They may be measured by placing a sensing device in the soil, to detect the stress. Many types of stress transducer have been designed and used for this purpose. Problems that arise and have to be solved in using stress transducers are: soil disturbance while placing the transducers, movement of the transducers, difference in rigidity of transducer and the surrounding soil, and the need for soil to adhere to the transducer.

NEUKAM [9] describes the development of a soil pressure gauge in use at German research institutes and pays special attention to a newly designed gauge for measuring soil stresses in laboratory conditions. Earlier versions of these gauges are also considered. The preliminary results of the latest version showed a high correlation between measured stresses and stresses induced by a triaxial test rig.

At the Tillage Laboratory of Wageningen Agricultural University it was hypothesized that soil stresses can be measured accurately if the pressure cell is embedded in the hard subsoil with the sensitive surface in plane with the boundary between firm subsoil and soft topsoil.
VAN DEN AKKER and CARSJENS [1] adopted this method for field conditions. Pressure cells were installed in two configurations. Two installation methods were used. The IMAG single-wheel tester was used to represent controlled traffic. An example of measured stresses is given in Fig. 8a. The peak stresses together with a calculation method resulted in an assumed stress distribution (Fig. 8b). The computed reaction forces were lower than the wheel load: 9.1 % and 9.7 % for installation methods A and B respectively. In a uniaxial (confined) compression test the pressure cell values were 1-3 % higher than the applied stresses.

SEVER [12] describes a rigid plate containing a number of pressure transducers. This device was used to measure soil pressures induced by forestry vehicles. Two vehicles were used: a 4x4 skidder and a 6x6 forwarder. Fig. 9 summarizes the measured stresses induced by the forwarder. Three vehicle loads and three measuring depths were used. From the values obtained with the forwarder it was concluded that soil pressures depend on contact plane and total load during wood hauling by forwarders.

GRECENKO [5] gives a table of tolerable soil stress at a depth of 50 cm, which is valid for fine-grained soils (a draft standard for the COMECON countries). The relevant load capacity of tyres and the consequent weight limits of certain agricultural vehicles were calculated. Fig. 10 shows the resulting estimates obtained for 14 agricultural tractors of one make. From this figure it was concluded that tractors above 55 kW engine power do not meet the requirements of the soil compaction theory satisfactorily and that tractors above 80 kW are too heavy. The same was found for most grain combines, forage harvesters and farm transport devices. It was concluded that technological development should concentrate on reducing axle load considerably, especially in powerful units. It should be mentioned that I prefer to use the term "wheel" load above "axle load" in this context. Use of wheel load gives a higher degree of freedom in choosing wheel configuration (number of wheels, distances between wheels, number of axles, etc.).

WHEEL-SOIL-CROP SYSTEMS

One one grassland field in South-West England DWYER and STADIE [3] investigated the relative damage caused by a tractor fitted with standard tyres, dual wheels or low pressure tyres. In each configuration the tractor axle weights and tyre inflation pressures were different. Soil penetrometer resistance, soil density, rut profile, and yield were measured. Measurements of rut profiles indicated that soil deformation was almost entirely caused by plastic flow. Their general conclusions were: the grass yield can be reduced by damage caused by wheeled vehicles. The lower the ground pressure of the vehicles, the less severe this damage is likely to be.

VERMEULEN and ARTS [14] describe a hardware model (true-scale loading frame) to simulate wheel actions in wheel-soil-plant research. This approach improves systematic investigation of the individual technical parameters in relation to load, loading techniques and soil and crop responses. The soil conditions achieved may be more uniform than in usual field studies. The set-up of the first two field experiments is described. One studies the effects of load on the regularly tilled rootbed (5-25 cm depth) of a annual crop (peas) during traffic in spring. The other deals with the effects of load on a once-tilled deep rootbed (0-50cm depth) for permanent grassland during year-round traffic. The use of the hardware model resulted in 2 m wide soil strips, which were uniform in horizontal direction. Extreme conditions in terms of cone resistance were achieved (Fig. 11). Characteristics considered important to model the wheel-soil-crop system were measured. Additional applied research should determine the similarity between currently available tyres and the model, so that tyres can be classified on their yield effects.

MILITARY TRAINING AREAS

Two papers, both from the Netherlands, were submitted on this topic.
A large area of Dutch heathland and shifting sands is used for military training. However, recreation and nature preservation are also important in these special areas. In 1981 the Dutch Ministry of Defence (MOD) commissioned research on the effects of off-road locomotion on the soil and vegetation. Three Dutch institutes cooperated in this research: RIN (Reseach Institute for Nature Management), STIBOKA (Soil Survey Institute) and IMAG (Institute of Agricultural Engineering).
ZWART [16] pays special attention to MOD's land-use policy and the background to the instigation of this research. The complementary paper by BEIJE [2] recounts the research set-up and the results. The following aspects were measured: rolling resistance, wheel sinkage, cone penetration resistance, nutrient level, cover of plant species, vegetation structure, and number of seedlings.
Some interesting results and/or conclusions:

- mechanical damage to the vegetation was a typical short-term effect; changes of soil properties and species composition were long lasting.
- soil compaction in heathlands persisted for at least twenty years.
- cone penetration values were often lower after soil disturbance than before. This effect was still present two years later.
- rolling resistance was often a good measure for the prediction of differences in the level of the effects.
- effects could be reduced by fitting wider tyres with lower inflation pressures.

This kind of cooperative research can supply relevant information for the management of military training areas.

FOREST SITE PREPARATION

GYLDBERG [6] studied torque and rotation on a disc trencher during forest site preparation. Preliminary results of an experimental machine are presented. Measurements on the device and experimental plot were made in order to improve understanding of the mechanism of the powered trencher and the performance of such a device.

CONCLUSIONS AND RECOMMENDATIONS

The papers reviewed reflect a growing number of specific methods to measure soil characteristics. Progress has been made in the continuous measuring of soil characteristics during field traffic, measuring vehicle-induced soil stresses, and measuring characteristics relevant to crop and vegetation responses. The interrelations between characteristics are hardly known and hopefully will receive more attention in future investigations. It is hoped that research on soil-vehicle interactions will continue to include the measuring of soil characteristics relevant to plant responses. This will help in the modelling of vehicle-soil-plant systems.

The research on vehicle-soil-vegetation systems can substantially improve the management of multifunctional military training areas.

It is strongly recommended to improve the documentation when research is reported. Information about vehicle and soil parameters is generally very incomplete. The same holds for test devices.

ISTVS is recommended to improve the terminology, documentation of measuring methods/equipment, and the exchange of research programmes, in order to enhance the quality and efficiency of research on terrain-vehicle systems.

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FIGURES GENERAL REPORT SESSIONS I AND II

4th EUROPEAN ISTVS CONFERENCE

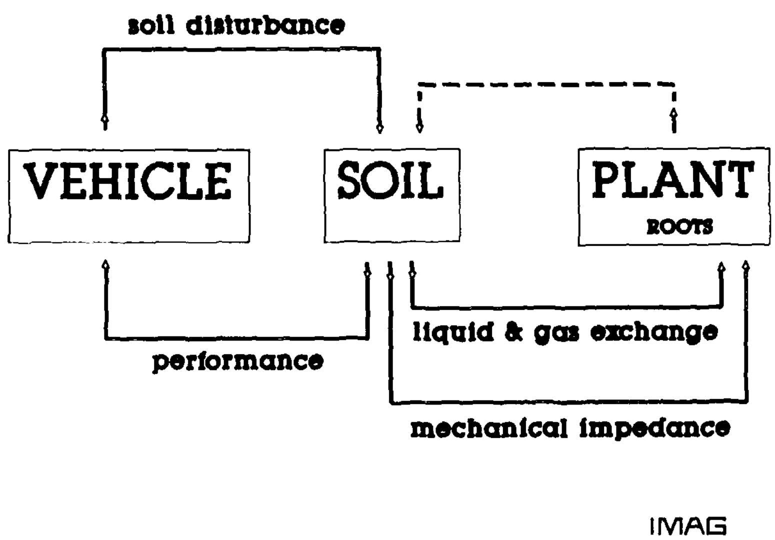

Fig. 1. Vehicle-soil-plant interrelations.

SOIL CHARACTERISTICS

Permanent soil characteristics

Transient soil characteristics
- volume/weight characteristics
- *soil mechanical properties*
  - *basic soil mechanical properties*
  - *empirical soil mechanical properties*
- *transport characteristics*

Fig. 2. Soil characteristics.

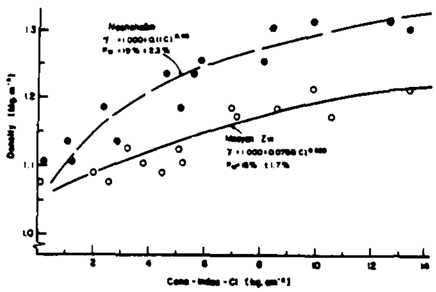

Fig. 3. Measured bulk densities as functions of measured cone index determined by penetrometer [7].

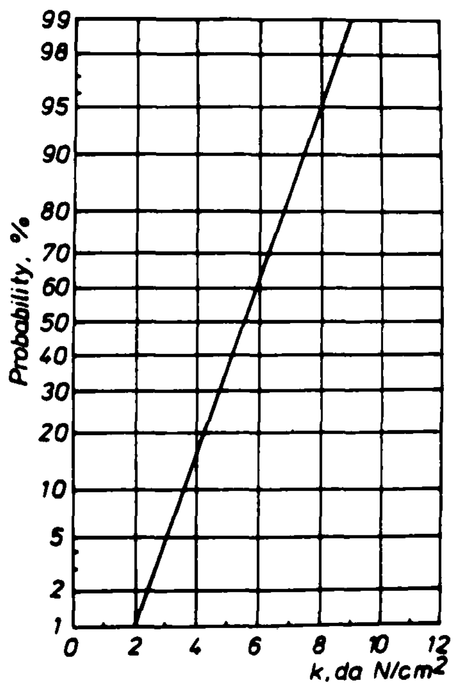

Fig. 4. Probability distribution of *k*-values for forestry soils in April [13].

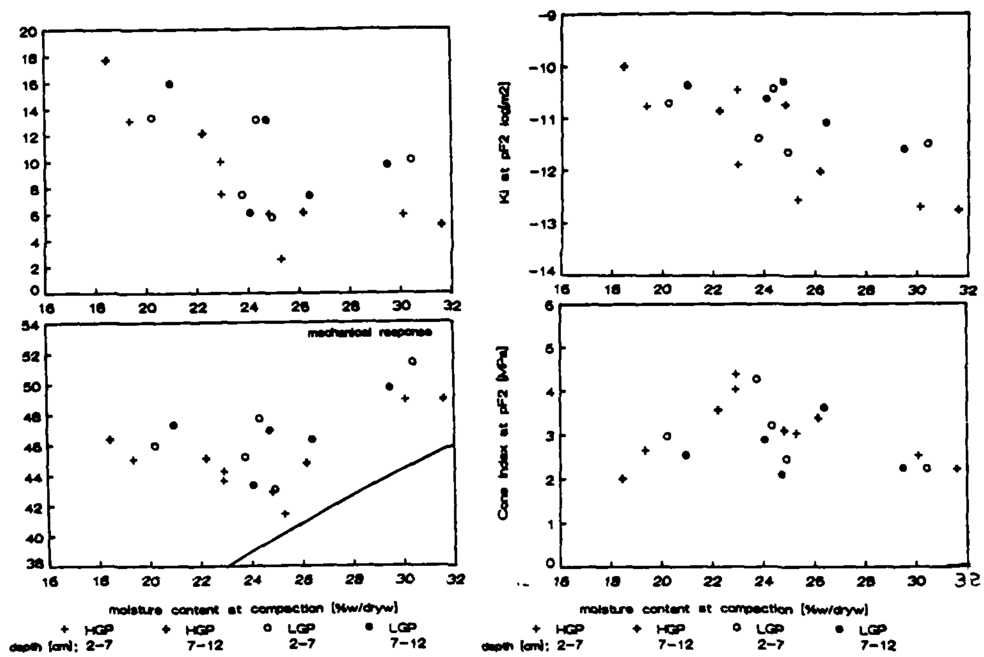

Fig. 5. Vehicle-soil diagram of seedbed preparation for root crops. The observed effects of vehicle traffic during seedbed preparation on soil qualities, as a function of the soil moisture content at compaction [8].

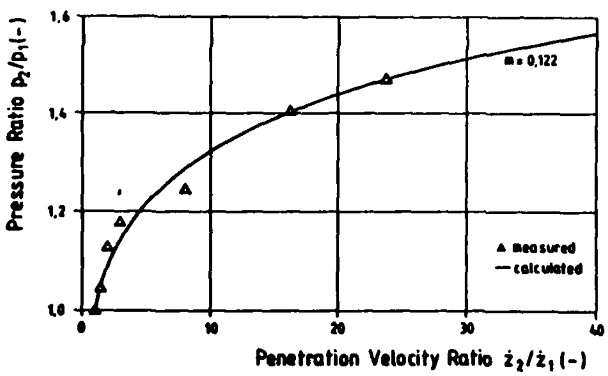

Fig. 6. Relation of pressure ratio to penetration velocity ratio [4].

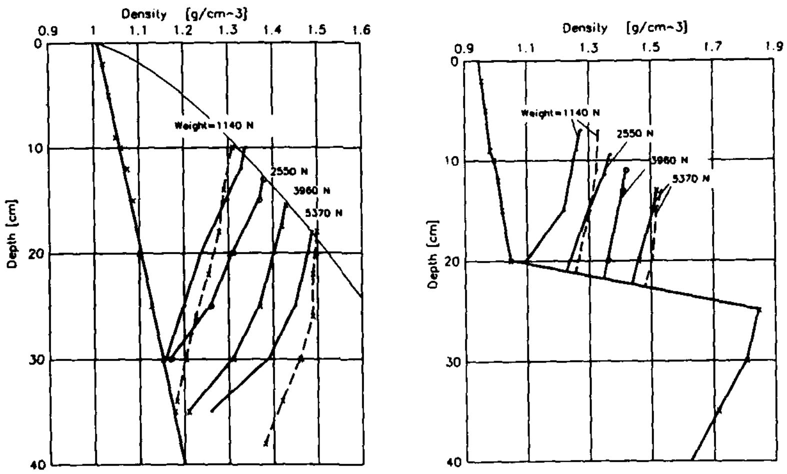

Fig. 7ab. a. Density of loose and compacted soil in relation to depth. The broken lines show the calculated relation.
b. *Density of loose soil with a firm layer* and density of this soil compacted by different wheel loads. The broken lines show the calculated relation [11].

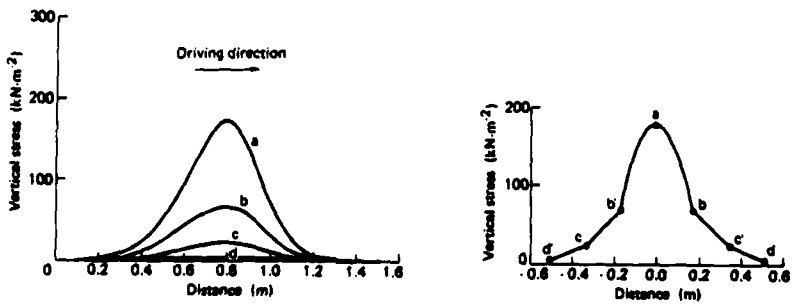

Fig. 8ab. a. Measured stress distribution during first wheel load. The centre of the wheel is at distance 0.8 m.
b. Assumed symmetrical stress distribution perpendicular to the drivinmg direction during first wheel load. [1]

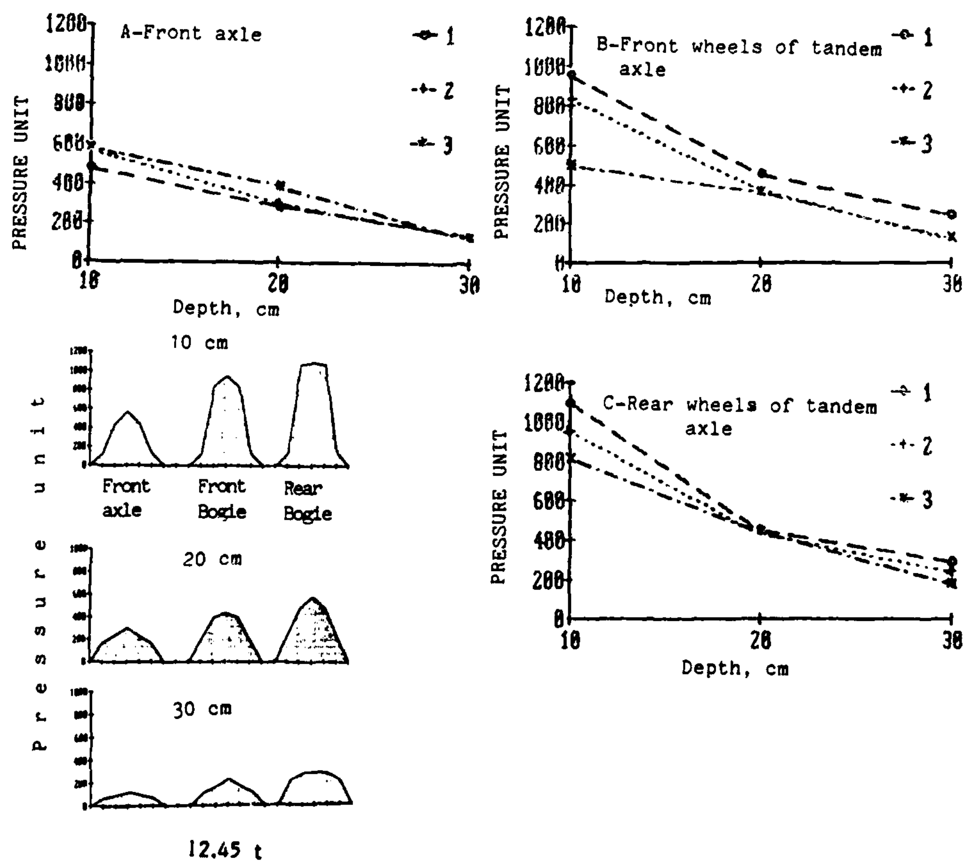

Fig. 9. Relationship between subsoil surface pressure and the depth for three different forwarder loads.
No. 1: 12.45 t
No. 2: 8.62 t
No. 3: 4.07 t. [12].

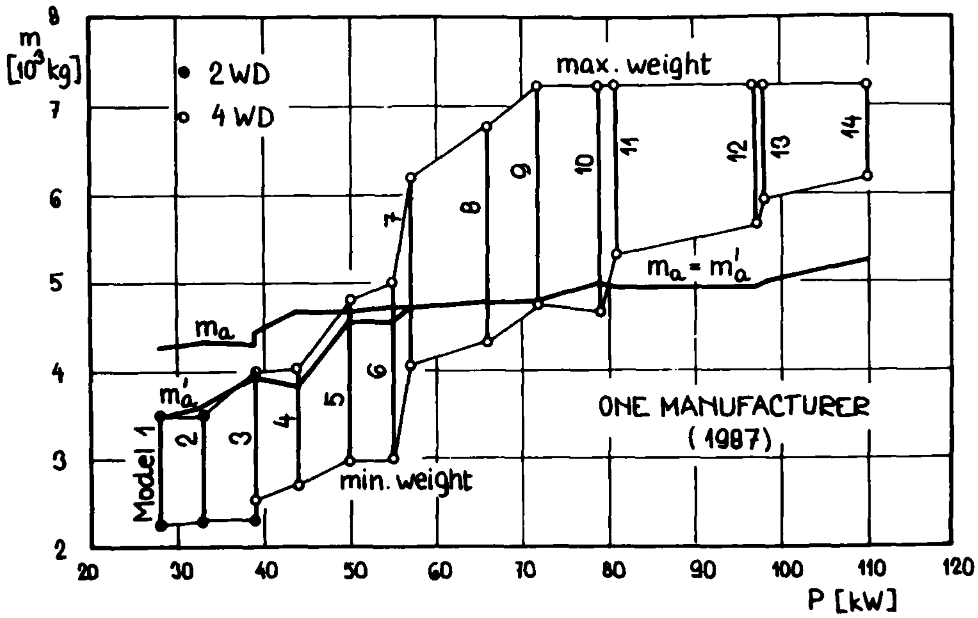

Fig. 10. Tractor weight - engine power relation for 14 models of agricultural tractors. m_a and m'_a are weight limits based on an alowable soil stress of 30 kPa at 50 cm depth [5]

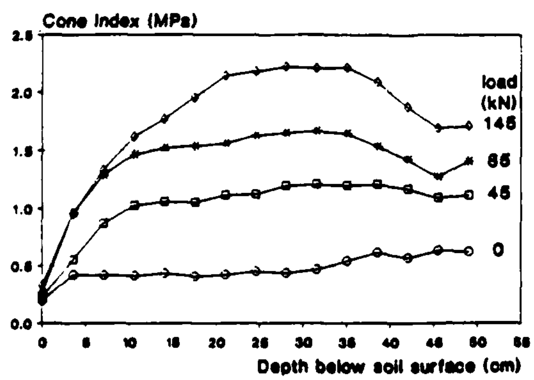

Fig. 11. Cone index on a fine sandy loam after passage of the loading frame [14].

ADVANCES IN MOBILITY DEVICES AND SOIL-VEHICLE MODELLING

E B MACLAURIN*

SUMMARY: This paper reviews progress in mobility devices and soil vehicle modelling as reflected in papers submitted to the Conference. These show the growing interest in methods for measuring and predicting the side force properties of tyres. Further refinements are reported in models for predicting the mission and route performance of vehicles. Other papers describe work on the vibration properties of tyres, tracked vehicle traction, soil compaction and component performance.

INTRODUCTION

Thirteen papers were submitted to Session III of the Conference. They can be divided into the following categories with obvious overlaps between the various topics.

Traction of tracked vehicles	1 paper
Side force properties of pneumatic tyres	4 papers
Sinkage and compaction due to pneumatic tyres	2 papers
Vibration properties of pneumatic tyres	1 paper
Vehicle and mission performance	3 papers
Component performance	2 papers

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TRACTION OF TRACKED VEHICLES

Kogure, Ohira and Yamaguchi (1) consider the thrust (or gross tractive force) which can be developed by a tracked vehicle when climbing a soil slope. The normal ground pressure under the vehicle is represented as a simple trapezoid to account for weight transfer due to the slope. An expression to represent this trapezoid is derived relating vehicle weight, track length on ground, track width, height of centre of gravity and slope. This appears to be an appreciable simplification of the pressure distributions under tracked vehicles reported by a number of other workers. Pressure concentrations occur under the road wheels depending on soil and vehicle track system properties. Also track tension forces tend to reduce loads under the front and rear wheels on vehicles with raised sprockets and idlers. Kogure et al reason that the shear process under a track system is essentially similar to that occuring under a laboratory shear test apparatus and use this method to measure soil properties in a field laboratory. They point out the similarity of the Coulomb shear strength equation - modified to include an exponential deformation term - and the frequently used exponential thrust/slip relationship. These two equations are combined with the normal pressure relationship to produce an equation for predicting vehicle thrust. No allowance appears to be made for the moment due to the height of the drawbar above the soil surface.

Results are shown for the thrust (assumed to be the total measured sprocket torque divided by sprocket radius) developed by a 7.5 tonne vehicle climbing a 13° slope of frictional volcanic soil. These measured results are compared with the predicted thrust curve. Although the maximum thrusts are very similar the measured thrust at slip ratios up to approx 10% are appreciably less than the predicted ones. This could point to the likelihood of pressure peaks occuring under the wheels. Considering Fig 6 of the paper the mean ground pressure is approx 0.65 kg/cm^2; at the higher pressures likely to occur under the wheels (say 1.2 kg/cm^2) it is seen that the shear deformations and hence slip ratios would be appreciably greater. No method for predicting external rolling resistance (and hence drawbar pull) is suggested.

SIDE FORCE PROPERTIES OF PNEUMATIC TYRES

The next four papers relate to various aspects of the side force properties of pneumatic tyres. El-Razaz and Crolla (2) consider a multi-spoke model - originally developed for road tyres - for predicting tyre in soil properties. Here the tyre is represented as a series of individual spokes which are free to deflect in the radial, longitudinal and lateral directions. Soil shear properties are modelled by the modified Coulomb relationship and pressure/sinkage by the Bekker relationship. A series of equations are developed relating soil and spoke deflections and force equilibrium to give the overall forces acting on the wheel at any slip/slip angle combination. Predicted results are compared with reported data for road and off-road tyres. Again no method for predicting the external rolling resistance acting on the tyre is suggested.

Armbruster and Kutzbach (3) describe a rig for measuring the longitudinal and lateral forces developed by driven angled tyres. The test wheel is carried in a 4 wheel trailer which can be coupled to the lower links of a tractor. The test wheel is carried on parallel links to accommodate ground uneveness and the rear wheels of the trailer can be angled to counter the side forces from the test tyre. Vertical load on the test wheel is controlled by a hydraulic cylinder and drive is by a hydrostatic pump and motor. Forces and moments on the wheel are measured by a 6 component wheel dynamometer mounted between the stub axle and supporting linkage.

Heine and Kutzbach (4) describe experiments to measure lateral forces, rolling resistance and moments on free rolling agricultural tyres. Two wheels are mounted on a trailed rig and angled against each other to cancel lateral forces and allow straight running. Forces and moments are measured by a multi-component dynamometer in one of the wheels. The wheels can be continuously steered against each other by hydraulic steering equipment to allow transient, non-steady measurements to be made. Results are shown for steady and non-steady experiments on concrete and off-road surfaces and for various steering rates and forward speeds. The non-steady measurements show the delay in the build up of side forces as the slip angle is increased.

Crolla and Maclaurin (5) describe a current research programme aimed at improving the overall steering, cornering performance and driveability of military vehicles. An important part of the programme has been development of a computer model to allow the steering performance of various alternative configurations of vehicle to be predicted. The model caters for most configurations of drive line including most types of inter wheel and inter axle differential. An essential input to the model is the combined longitudinal/lateral force properties of pneumatic tyres in soft soils. To acquire further information on these force properties the RARDE Mobile Tester is being modified to a configuration similar to that described in the previous paper with a pair of wheels angled against each although in this case they are driven by hydraulic motors. Individual force transducers are used rather than the multi-component wheel dynamometers described in the previous two papers. A test vehicle is also being constructed to a) help validate the computer model and b) investigate various methods of controlling overall wheel slip and distribution of slip between the wheels.

SOIL COMPACTION

Bolling (6) reports results from a laboratory investigation using a modified triaxial test machine to measure the porosity reduction of soil samples. Variables are initial porosity, density, water content and pressure ratio. These results are combined with the pressure bulb theory and estimates of tyre contact area to predict likely reductions in porosity in field soils caused by various farm vehicles. Results are shown for different tyre loads, contact areas and harvesting methods.

Ronai (7) reports the results of tests in soil bins to measure sinkage and rut profile as affected by tyre load, slip, inflation pressure, tyre width, diameter and carcass construction (radial or cross ply). Some empirically derived relationships are suggested.

VIBRATION PROPERTIES OF PNEUMATIC TYRES

Meyer, Siefkes and Gohlich (8) describe the results of tests on the vibrational characteristics of rolling agricultural tyres. Two rigs were used for the tests: a) a laboratory flat-bed rig and b) a trailed outdoor rig. The rigs are of the same basic construction to allow easy comparison between the two. Tyre self-excited vibration can be caused by lack of uniformity and/or out-of-balance. The authors suggest that driving safety is best described by the 'Dynamic Load Factor' which relates the minimum rolling dynamic load to the static tyre load. Dynamic Load Factors are shown as functions of speed and inflation pressure. Tyre rolling stiffness and damping was measured by two methods: a) by calculating the transfer function with a random signal input and b) by free oscillation tests. The first method is preferred but cannot be used with the outdoor rig. Results are shown as functions of speed, inflation pressure, tyre size and construction, and various types of tyre filling (gaseous, liquid and foam). Results are also shown comparing measurements on the laboratory rig, hard road and in soft soil.

VEHICLE AND MISSION PERFORMANCE

Heiming (9) considers the likely effects of soil strength variability on the levels of vehicle mobility predicted in such models of the NATO Reference Mobility Model (NRMM). Cone penetrometer measurements on a particular site nearly always show considerable scatter. Methods have been developed to calculate the number of measurements required for a given confidence level of mean and standard deviation of soil strength. It is suggested that the variation in soil strength can cause a vehicle to become immobilised when this would not be indicated by the mean level of cone index. However consideration would also need to be given to other factors such as the size of the vehicle, number of wheels, type of transmission (free or locked differentials) and the speed of the vehicle. It would be interesting to see the work extended so as to include some factor which would account for the area over which soil strength measurements were made.

Laib (10) reports on a model for predicting the ride limited cross country speeds of vehicles. The model is one part of an overall vehicle performance prediction model. Terrain profiles are described by their statistical properties and used as input to a three dimensional vehicle suspension model. Results are shown for two vehicles as plots of permissible vehicle speed against terrain roughness for two levels of driver acceleration. The predictions have been validated by vehicle tests on 7 terrain surfaces.

Melzer (11) describes the effects of including a skid steering sub model in the NATO Reference Mobility Model (NRMM). This skid steering model was originally developed at Waterways Experiment Station (WES) in the US. The Battelle version of NRMM (called BMM) includes a traverse or route mode. Previously no reduction in vehicle speed occured when changing direction in curves. The traverse mode also includes limiting speeds for obstacles and acceleration/deceleration between obstacles and curves. Inclusion of the skid steer model has further reduced errors (to about 4%) between measured and predicted mission times for a 40 tonne tracked vehicle.

COMPONENTS AND COMPONENT PERFORMANCE

Hohl (12) describes tests conducted on two 'run flat' tyre systems, ie systems to allow tyres to run without inflation pressure for emergency purposes. The first system is an elastomer insert which fits between the beads of a conventional radial ply tyre thus providing support for the tread when deflated and locking the tyre beads to the wheel rim. The system adds only about 2.75% to the weight of a 17 tonne vehicle. The second arrangement is a polyurethane foam tyre fill system again used with a conventional tyre. This system is considerably heavier adding 10.6% to the weight of a 3.5 tonne vehicle. In contrast to the elastomer insert system the foam fill system only has the one operating condition and not an inflated and emergency state. Tests included those for durability, handling, acceleration and rolling resistance, ride comfort and tyre stiffness characteristics. It was concluded that both systems achieved their basic function of keeping vehicles in operation after puncture without unduly impairing normal vehicle mobility levels.

Rigamonti and Zarotti (13) describe various control strategies which are available for vehicles with hydrostatic transmissions. A unified control will optimise settings for the different components (engine speed and load, hydrostatic flow and pressure) according to the required strategy (performance, fuel consumption etc). One implementation is by pilot pressures but the future lies with microprocessor control.

CONCLUSIONS AND RECOMMENDATIONS

It is difficult to draw any general conclusions from such a variety of papers. However there is a noticeable amount of work proceeding on the side force properties of pneumatic tyres; hopefully this will lead to well established methods for predicting the steering and manoeuvring performance of vehicles in soft soils.

The work on the vibrational properties of tyres will be of considerable value to those working on models for predicting the ride performance of sprung and unsprung vehicles. The work also has lessons for tyre manufacturers in ensuring the highest standards of quality control. Steady progress is being made with automotive mission performance prediction models. The work on soil strength variability will hopefully be taken further and will add further refinements to these models.

Some papers show soil/component performance measurements with little or no reference to soil strength properties. For all its shortcomings the cone penetrometer provides a cheap, quick and simple method of taking measurements which give useful insight especially when used in conjunction with other soil characteristics.

Papers on components and component performance are always of interest and should be encouraged; they will help the Society gain the support of manufacturers who may be deterred by an excess of overly specialised papers.

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SOIL COMPACTION AT WOOD HAULING AND WOOD SKIDDING WITH HEAVY-DUTY TRACTORS

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Summary

Investigation of forest site treading and soil compaction started with the beginning of the logging mechanization. The goals of this research were the percentage of the wheel rut area, rut depth and the cone penetrometer test at the wheel track, especially for the overloaded ground. The paper deals with lab-terrain methods of measuring soil compaction by two kinds of wood transport: skidding of wood with skidders and hauling with forwarders. A simple compact beam with 6 or 10 measuring transducers, uncomplicated to use, was used as a measuring system. Besides finding the soil compaction by vehicle wheels, the investigation was carried out by overloading of tractor axles, change of pressure per tyre width. etc.
Key words: soil compaction, skidder, forwarder

Introduction

An abrupt development of mechanization in forest exploitation started in the 1970ies. At the beginning of this period, many of the then used transportation engines did not correspond with the purpose. The high amounts of the acting tractor forces at wood skidding undoubtelly caused deep wheel ruts, soil compaction and root damage, while the bad organization of the work resulted in a high percentage of treading. The knowledge on which forces can be born by the stand soil is still limited. The allowable loading of the wheel, or the so called flotation (Bekker, 1956) is frequently the required parameter for choosing and planning skidder performance. The demand for higher loading and trafficability was commonly explained by lower sinkage, pressure and wheel slippage, and thus by greater contact surface with lower contact pressure. The technical problems in achievement of these requirements have still

been unconquerable.

There is a real danger of subsoil compaction at forest exploitation. Depending on the research goal at soil compaction investigation, the factors to be established are rut depth, wheel track profile, pressure on the contact surface of the wheel and soil, pressure at various depths under wheel track, etc., all depending on the axle load, dynamic charge, slippage, etc.

The results of investigation should help at classifying forest terrains, establishing tractor types according to the available power, understanding of the forces transfer upon the ground, etc.

Review of previous work

The investigations of soil compaction have been common in agriculture, building, mining and army, whereas in forestry they have been rare. In determination of soil properties as regards its compaction, Nominal Ground Pressure - the NGP (Larminie, 1988) - has been used for a long time, as defined from the proportion of weight on the vehicle support evenly distributed upon the flat contact surface. The surface of the caterpillar tractor is easily determined by multiplying the width and length of the caterpillar, whereas wheel tractors have two NGP forms: tyre manufacturers take into consideration the contact surface of the tyre upon hard ground, and in exploitation research, the tyre surface in the rut that causes stopping of the vehicle. For military purposes, the criterion for ground pressure is the Vehicle Cone Index - the VCI. Another unit of the highest vehicle pressure, the Mean Maximum Pressure - the MMP, is established by measuring of the real pressures under the vehicle. The MMP for wheel tractors is also based on understanding soil classification.

Forest tractors are constructed with bigger specific volume (kg/kW), so that, say, 1 kg skidder bears an essentially lower amount of the engine unit power than the agricultural tractor (Sever, 1980). Among others, this is explained by performance under unfavourable adherance conditions followed by significant soil compaction.

For the needs of terrain classification of Canadian Forestry (Mellgren 1980), in the same way as has been suggested for Sweden (Anon., 1969) and some other countries, the authors speak of three major factors influencing the off-road mobility of the vehicles: ground conditions strength, ground roughness, slope. For practical purposes they introduced the Standard Ground Contact Pressure - the SGCP - for off-road vehicles by calculating the Rated Footprint Pressure - the RFP - using simple equations.

Soil disturbance followed by creation of ruts, shifting and pushing of soil, etc., is also a consequence of ground-skidding or one-end-up-hauling (Calvert & Garlicki, 1968).

Bekker's definition after Wästerlund (1988), whereby the soil-vehicle system in forestry is a new field requiring special solutions, has frequently been confirmed in practice and science (Bekker, 1973). It has been here established, that soil bearing capacity is reduced in proportion with reduction of the width of the surface skeletal forest layer.

Ronai (1986) established that soil compaction is an unavoidable, unwelcome effect caused by loading the wheel, caterpillar or similar load, a result of complex effects of horizontal and vertical loading.

Procedures, equipment and apparatus

For the purpose of determination of the pressure under skidder wheels, a charasteristic base for making a field experiment of soil compaction was sought. The pressure upon every wheel in the contact plane was determined by weighing, and the contact plane was calculated or determined by planimetric survey of the print, whereas the pressure in the subsoil was measured at the depths where the impact of the tyre profiles ceased (Piria, 1977).

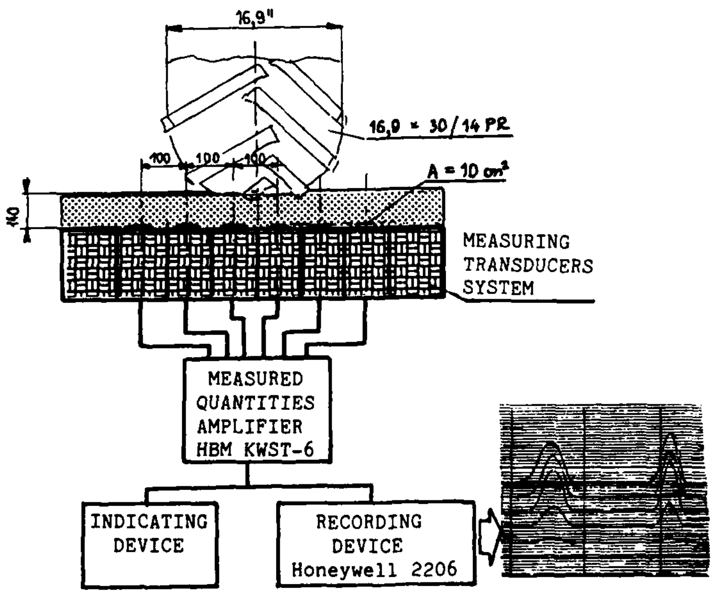


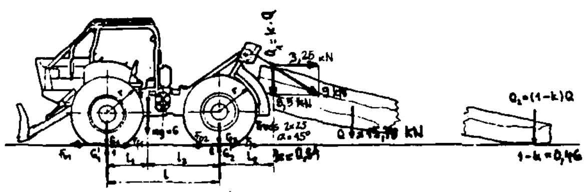
Figure 1. Shematic review of the measuring chain for measurement of soil pressure with oscillograph record.

Figure 1 presents a measuring system with one record, made after a similar one used in agriculture (Piria, 1973). Depending on the tyre width, there has been a system of 6 or 10 measuring force transducers with a steady active plane of 10 cm², at a distance between each of 100 mm. The transducers are connected together in a firm housing, 125 mm high and 700 mm or 1100 mm long. It is connection of the transducers in a firm housing, which is the main disadvantage of the measuring system, as it disturbs the soil structure at building-in. On the other hand, the fast building-in is an advantage, as well as easy repetition of the measuring, and gauging of the device, all enabling a great number of measurements within a relatively short period of time.

Skidding machines of 3rd generation were used: skidders and forwarders. At investigating the skidders, the pressure was measured at a depth of 14 cm and hauling of the load carried out at a horizontal skidding component of 3.25 kN and vertical component of 8.5 kN.

Results of the experiments as a preliminary note

The investigated skidder was of a medium category, while the forwarder belonged to the heavy-duty vehicles of this type. Figure 2 shows axle loads of the examined skidder, and figure 3 the ones of the 6x6 formula forwarder.



1,2 bar | 1,4 bar
3190 cm² | 3190 cm²

16,9-30/14 PR

Unloaded

37,5 kN | 29,3 kN

56,20 kN

66,7 % | 33,3 %
p_f=58,5 | 29,3 kPa | Formula
p_{mean}=236 | 178 kPa | Experiment
p_{max}=119 | 77,6 kPa |

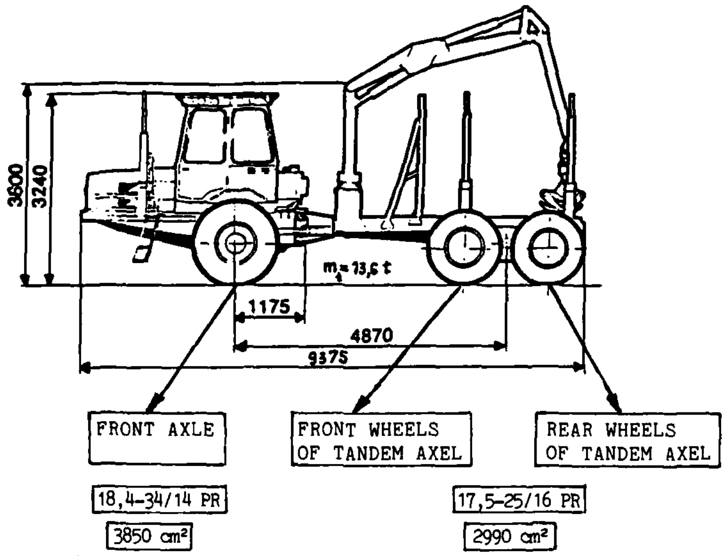
Skidding

32,9 kN | 31,68 kN

64,7 kN

51 % | 49 %
p_f=51,7 | 49,65 kPa | Formula
p_{mean}=94 | 116,5 kPa | Experiment
p_{max}=239 | 218 kPa |

Figure 2. Some characteristics of the 4x4 wheel formula skidder.



Empty		76 kN	34,6 kN	36 kN
		98,7 kPa	57,7 kPa	60,2 kPa
Loaded		76,5 kN	103 kN	31,5 kN
		99,3 kPa	172,2 kPa	153 kPa

Figure 3. Heavy-duty forwarder of the 6x6 wheel formula; Wheel characteristics and pressure in them.

Besides the tyre properties and the calculated contact planes, axle loads for unloaded and loaded vehicle are presented.

Besides the current moisture and granulometric soil composition, the penetrometric characteristics of the soil was established by means of a cone penetrometer.

Figure 4-A and B shows the pressure under skidder wheel established by the above described measuring system at a depth of 14 cm. Figure 4-A shows five highest established pressure values at a distance of 100 mm each at unloaded moving of the skidder.

The pressure in the middle zone was 47 % higher than the one in end zones. By suspension and hauling of the load, the front axle is unloaded; the maximum pressures remain nearly the same, while the ones in the nearby zones drop to about 40 % of the highest amounts. In order to avoid confusion and comparison of the values that were established by gauging in kPa, the so-called conditional pressure units are expressed on axis y.

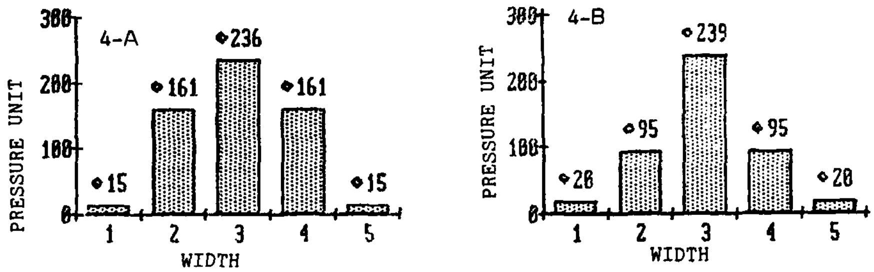


Figure 4. Presentation of measurement results of pressure upon the width of the unloaded/loaded front axle skidder's track (rut).

Figure 5-A and B shows identical diagrams of the rear axle of the skidder; figure A, for unloaded tractor, and B for the tractor during skidding. Here were established reverse phenomena to the ones on the front axle; the empty rear axle was considerably underloaded, and by skidding of the load it became loaded and showed the properties of a front empty axle.

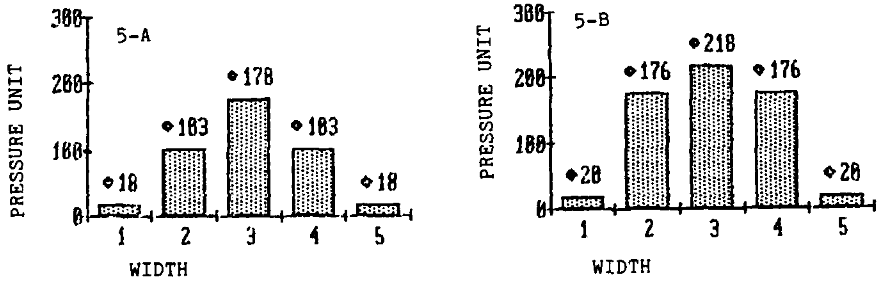
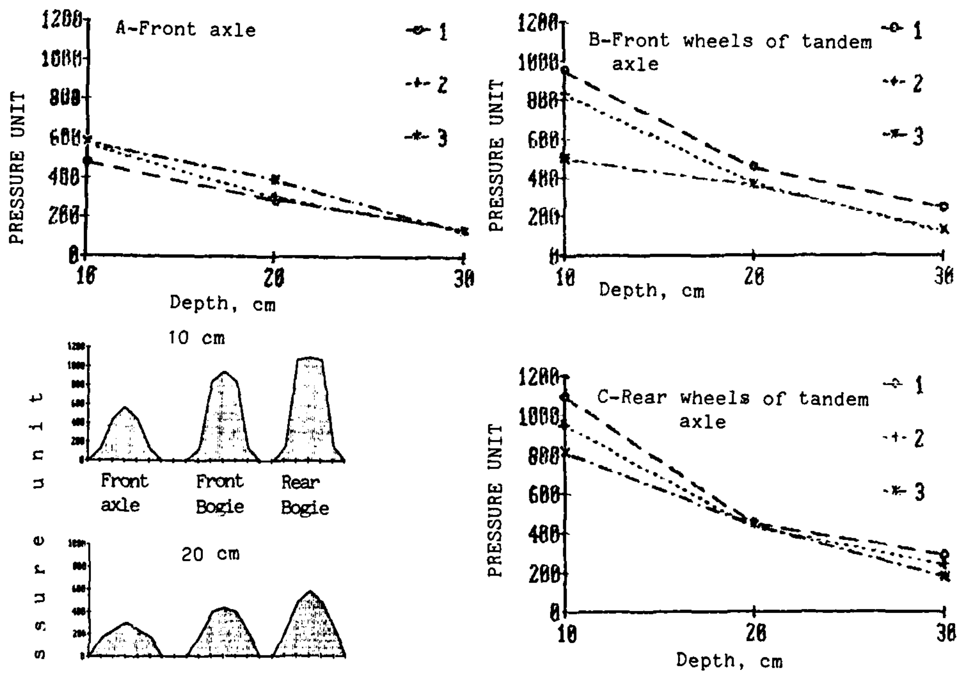


Figure 5. Presentation of measurement results of pressure upon the width of the unloaded/loaded rear axle skidder's track.

The investigation of the pressure in subsoil at transport of the load by forwarder was carried out on three horizons: 10 cm, 20 cm, and 30 cm deep. At this the loads were changed. 12.45 t, 8.62 t and 4.07 t. The results are shown in Figure 6-A, B and C, as a summarized diagram for three depths and three loads. Figure A refers to the front forwarder wheel, whereas Figures B and C for the front and rear wheel of a bogie. The front wheel of the forwarder can be refered to as an even decrease of the pressure for the whole observed depth area, while the bogie wheel has a decrease to the depth of 20 cm as more distinguished than one at greater depth.

Conclusions

Minimization of soil compaction is influenced by choice of tractor and tyres, preparation and organization of work, technological processes in forest exploitation, etc.



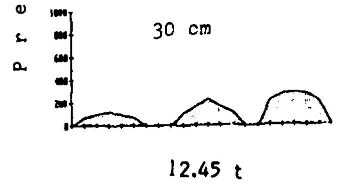


Figure 6. Relationship between subsoil surface presure and the depth for three different forwarder loads Nr. 1-12.45 t; Nr. 2-8.62 t; Nr. 3-4.07 t.

The applied measuring system yields information on the pressure and weight under the wheels of forest vehicles, though only relative indices such as the cone index - CI.

The dynamic loading for all profiles of the compacted zone increased in proportion with the increase of the width and pressure. The intensity of the pressure in a particular zone per profile is in a functional connection with the intensity of deformations, that is with the degree of soil compaction. On skidding strips and road-side landings, there is a phenomenon of an increased hardness of the horizon in subsoil. The research showed that the pressure at hauling by forwarders, as measured in three points, depends on the contact plane and total load, under contact soil surface; with skidders, it also depends on the effected skidding force.

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WORKSHOPS

GENERAL INFORMATION

The workshop was prepared by the organizing committee as found in the next two pages.

The topics were:
A Agricultural and forestry aspects of Session I
B Military aspects of Session I and Session II
C Advances in Mobility Devices and Soil Vehicle Modelling

The groups should also generally discuss ISTVS' role and ambitions.

The three groups reported in a presentation session. The findings of the groups were presented by Mike Dwyer, Uno Björkhem and Klaus Melzer. The reports are included on page 51-64.

The general questions are reported in the general discussion (page 64).

4th EUROPEAN ISTVS CONFERENCE — 21-23rd March, 1989, Wageningen, the Netherlands

"WORKSHOPS"

Conference theme: **"Terrain-Vehicle Systems and Sustained Soil Quality"**

Session I : "Field Traffic and Sustained Soil Quality for Plant Growth"
Session II : "Vehicle Systems and Soil Quality for Military Training Areas"
Session III: "Advances in Mobility Devices and Soil-Vehicle-Modelling"

WORKSHOPS : Tuesday 21st March 15.00-17.00 h
Thursday 23rd March 13.00-14.00 h *(round off)*
15.15 presentation of conclusions (15 min. per group)

We would like to devide the delegates in 3 groups:
Group A. Agricultural and forestry aspects of Session I.
Chairman/secretary: **Wismer/Dwyer**
Tuesday : "kleine zaal" at IAC
Thursday: "kleine zaal"at IAC
Group B. Military aspects of Session I and Session II.
Chairman/secretary: **Areskoug/Björkhem**
Tuesday : Room G at IAC
Thursday: "ir Haak zaal" at IAC
Group C. Advances in Mobility Devices and Soil-Vehicle Modelling
Chairman/secretary: **Melzer/Crolla**
Tuesday : Room A at IAC
Thursday: Conversation Room at IAC

Each group will have 15 minutes to present their conclusions.

It is our goal to include the conclusions of workshops in volume 2 of the proceedings.
Please submit the final text of the workshop conclusions before 15th April 1989 to the Conference secretary.

On the next page you will find some questions that may be useful to discuss.

QUESTIONS FOR WORKSHOP LEADERS

General

A Can ISTVS be active in strategic planning in European R & D ?

B Can ISTVS stimulate exchange of R & D programmes ?

C "Europe 1992" : consequences for programmes?

D ISTVS working groups in special areas (regional) desirable ?

E Can ISTVS play a role in fund raising for R & D programmes ?

Technical items

1 Consequence of "new" rubber tracks.

2 Gantry - LGP (state of the art)

3 Industrial crops; perspective, consequences for technique?

4 Polyurethane tyres.

5 Tyre profile related to soil and crop effects.

6 Models, how to make them useful for practical use ; expert systems ?

7 Rules for field traffic ; necessary ?

8 Measuring relevant soil characteristics, standardization of procedures and equipment.

9 How to integrate soil and crop responses in R & D programmes, consequences for programme set-up.

10 Developments in military vehicles:
- mobility
- running gear
- mission orientation

Workshop Report - Group A

Field Traffic and Sustained Soil Quality for Plant Growth - Agricultural and Forestry Aspects

The initial discussion in the workshop was concentrated on whether or not it was possible to set limits on loads, ground contact areas or pressures which would avoid the risk of excessive soil compaction. Many speakers emphasised the danger of oversimplifying the problem and pointed out the many factors such as soil type, moisture content, future weather pattern and the crop to be grown, which would all affect the results of compaction. Nevertheless, others felt that, despite these difficulties, it could be helpful to set certain guidelines or targets to be achieved by commercial equipment. Amongst these were a maximum axle load of 6 tonnes, a maximum ground contact pressure of 100 kPa and a maximum pressure of 30 kPa at 0.5 m depth in the soil. The predominant factor affecting soil compaction is load and, therefore, an axle load limit is attractive. On the other hand, the 30 kPa pressure at 0.5 m depth has merit in corresponding to levels common in the 1950's and early 1960's in Europe, when soil compaction was not considered to be a serious problem.

Other factors which affect soil and crop damage were also discussed, in particular wheel-slip. It was suggested that wheel-slip greater than 12-14% could be very damaging on grassland. This led to discussion on the extent to which traction on grassland is generated by friction between the tread bars and the grass surface or by shearing of the soil and grass root mass between the tread bars. This in turn, of course, depends on the degree of tread bar penetration and the height of the lugs. 25 mm was said to be sufficient height for lugs for operation in homogeneous soils, but higher lugs may be necessary in layered soils. The possible application of rubber tracks was raised in this context and it was

pointed out that they had been shown to give improved traction and reduced ground pressure. However, very little data is obviously available as yet.

The importance of moisture content in determining soil compaction effects was stressed and it was pointed out that the moisture content of soil at compaction affected not only the compactability, but also the structural strength change.

The discussion then moved on to consider practical methods for reduction of soil compaction and, in particular, central tyre inflation systems. Such a system was said to have been available for agricultural vehicles in the Netherlands since 1986. It could change inflation pressures within 5 to 10 minutes. Such systems had also been considered in Sweden, but had not been adopted in agriculture, although there was some possibility of their being introduced in forestry in the future. It was felt that they would appear in the USA in the future. The use of fillings for tyres was also mentioned in this context, since they reduced the time taken to change pressures. They were said to be only suitable for military applications, but the dynamic effects of water filling increasing damping was also mentioned.

The workshop then moved on to consider the question of whether ISTVS could become active in strategic planning in European research and development and/or stimulate the exchange of research and development programmes. The need for a database of research programmes was expressed, but no one could see how this could be achieved with present resources.

It was pointed out that ISTVS had in the past had working groups to study such topics as standardisation and the suggestion was made that a working group should be set up on soil/crop response. ' This group could perhaps attempt to develop the best models for soil compaction and crop growth from among those which are currently being developed independently. However, it was also necessary to be clear what the purpose of the model was. For example, there were at least the following three possible reasons for developing a model:

1. To enhance understanding of a process
2. To use for practical decision making
3. To use for design

The importance of including time effects in a model of soil compaction was discussed and work on this topic at several places by people not represented at this conference was mentioned.

The discussion then moved on to consideration of tractive performance. Many speakers pointed out that the increases in ploughing speeds expected 20 years ago had not materialised, although there had been a modest increase year by year. This was felt to be due to the increase in plough draught with speed, which, although not always as great as originally claimed, appeared to be unavoidable. Those ploughs specially developed to minimise the increase of draught with speed were found to be very speed-sensitive and only worked properly within a very narrow speed range.

The question of replacing draught cultivation implements with powered implements was discussed, but it was generally felt that the extra complication of moving parts was a strong disincentive to potential implement purchasers. This was despite the reduced complication of modern spading machines in the Netherlands and the good performance recorded with the rotadigger in UK.

The conclusions of the workshop were that the most valuable contributions which ISTVS could make to progress in this area would be the following:

1. The setting up of a database of relevant research programmes.

2. The setting up of a working group to develop universally acceptable mathematical models to describe soil/crop response.

M.J. Dwyer

4th EUROPEAN ISTVS CONFERENCE WAGENINGEN MARCH 21-23 1989

Workshop B: Military aspects of sessions 1-11

Chairman: Stig Areskoug

Secretary: Uno Björkhem

The workshop had two meetings, Tuesday March 21, 1500-1700 and Thursday March 23, 1300-1400. In the first meeting 25 delegates were present from 8 different nations, in the second meeting 13 delegates were present.

The workshop agreed on the following general base for the discussions:

> "The excercise fields are limited and in conflict with other land uses and with the necessity of excercise and training".

The following discussion focused on three main points:

1. Vehicle factors
2. Operational factors
3. Soil factors

and the factors that should be considered were listed

1. Vehicle factors:

- weight
- ground pressure (MMP)
- tyre size, design
- threads-grousers
- steering
- power/weight ratio
- total weight/overall area ratio
- number of driven axles
- slip
- number of passes
- dynamic factors

2. Operational factors

- how, when and where to drive
- simulators
- fake vehicles
- peace-time running and restoring costs

It was pointed out that the drivers experiences from realistic training were important. Today restoring costs are not fully paid.

3. <u>Soil factors</u>

- land use
- soil preparation
- soil reinforcement (geotextiles, mats)
- prediction: Different soil parameters.
  How and what to investigate
- users ignorance of soils

The headline "Prediction" lead the workshop to the general questions prepared by the organizing committee.

The following suggestions of ISTVS' activities were discussed:

4. <u>What should ISTVS do?</u>

- compilation of existing standards & methods
- agreement on - parameters
  - soil investigation & test methods
  - directions for the use of methods
- models/model use/for practical work.

These suggestions in several cases coincided with the proposals from workshops A & C.

The workshop concluded its work by some suggestions how this work could be done:

A rapid issuing of ISTVS standards to a broad target group was agreed upon. Working groups for compilations of new standards and models could be a second step in the work. Finally, priorities for standards and models to work on should be made.

An improvement of the membership and a letter marketing of ISTVS were looked upon as an urgent support for the work.

Uno Björkhem reported the workshops findings in the closing session at the conference, Thursday March 23rd.

SUMMARY OF WORKING GROUP "SESSION III" ON ADVANCES IN MOBILITY DEVICES AND SOIL-VEHICLE MODELING

Chairman: K.-J. Melzer, FRG;
Secretary: D.A. Crolla, UK

1 INTRODUCTION

This paper summarizes the course and results of the group discussion dealing with the theme of Session III and general subjects. This summary is divided into four parts:

- The tasks
- The method
- The results
- Conclusions

The group consisted of 25 people from eight different nations. Analyzing the group according to the types of employment one obtains the following picture:

o Industry:	2
o Universities:	17
o Government agencies:	5
o Private research and engineering institutions:	1

The distribution of the areas of interest was as follows:

o Agriculture:	9
o Forestry:	1
o Off-Road Transport/Military	9
o General:	9

Generally, it can be stated that the industry (manufacturers) and equipment users were underrepresented in this group, which was dominated by researchers from universities and government agencies. This fact has to be considered when weighing the results.

The discussion consisted of two parts. In part I (22 March, 15:00 - 17:00 hrs), specific technical and ISTVS related items were discussed; in part II (23 March, 13:00 - 14:00 hrs), the audience had the opportunity to ask questions about the papers that had been presented in the morning session; unfortunately, about half of the authors had already left the conference at that time and did not take their stand; the chairman deeply regrets this and apologizes to the remaining participants and to the organizing committee who certainly deserved more attention.

The discussion was held in English; there appeared to be no language barrier during the three hours we worked together. The chairman takes this opportunity to thank the participants once more for their cooperation.

2 THE TASKS

From the technical and ISTVS related items suggested by the organizing committee the following were chosen and discussed:

Task 1: Models - how to make them suitable for practical use.

Tasks 2: Tasks for ISTVS in regard to future recommendations/-standards, especially how to deal with the standardization of procedures/equipment to measure soil properties.

Task 3: ISTVS and Europe 1992

3 THE METHOD

Basically, the method of open discussion was used in the working session. This was supported by some "brainwriting" in obtaining results for task 1. These results can only be summarized here.

4 THE RESULTS

4.1 Task 1: Models

In a first step, the group defined the models it considered, according to type and area of interest. The results are summarized in table 1. Main areas of interest were agriculture and off-road transportation/military with emphazis placed on models treating the problem of soil-running gear interaction. There appeared to be a shift of emphazis in comparison to a similar - but more comprehensive - analysis made during the 1rst European Conference of ISTVS in 1980. At that time dynamics/ride comfort was considered more important than the soil-running gear interaction; however, the emphazis on overall system modeling has increased since then.

In a second step, the group identified the type of models in use and in which areas they are applied; two areas were identified for this:

- Vehicle user
- Designer, developer, manufacturer

The results are summarized in table 2. It is interesting to note that the treatment of the overall system seems to gain ground, which is reflected in the key terms "mission performance prediction" and "mission oriented design".

An extensive discussion of the results obtained so far finally led to the identification of the orientation and directions which

future model development should take. The following two directions were seen by the group:

- o Accurate (credible) dynamically operating models (vehicle systems as well as subsystems) e.g.: Vehicle performance → (power, traction, safety, comfort etc.) → driver performance → soil compaction → environment (e.g. plant growth)
- o Overall models "talking to each other" meaning practicable/ user friendly interaction of the systems mentioned above.

The following warnings/reminders were issued to the model developers and users:

- o Use correct input parameters
- o Be sure how to determine/measure your input parameters
- o Validate compatibility between existing models and data bases and new developments by maintaining/establishing ties between input parameters.

4.2 Task 2: Tasks for ISTVS

In view of the discussions of task 1, especially the future directions modeling will take, the group recommended that ISTVS takes on the following two tasks:

- o Standardization of model interfaces. This appears to be especially important if one considers future overall models "talking to each other" interactively. The establishment of a corresponding task force seems to be necessary.

- o Determination (e.g. measurement) of terrain characteristics (soil etc.) for off-road mobility. It has been recommended to turn this task over to the existing standardization

committee of ISTVS that should proceed along the following outline to optimize the efforts involved:

- oo Publish existing ISTVS standards (beyond ISTVS membership!).
- oo Review/identify standards of other engineering disciplines suitable to our needs.
- oo Identify regional standards and practices that may fit our needs.
- oo Identify remaining characteristics to be standardized.
- oo Recommend to existing standardization committees to include these missing characteristics into their efforts.
- oo Avoid rigid standardization to maintain the flexibility to dwell on regional practices, experiences and data bases.

4.3 Task 3: ISTVS and Europe 1992

An extensive discussion of the possible role of ISTVS within a united Europe after 1992 lead to the following recommendations:

- o ISTVS cannot be considered such a strong professional society that it could get actively involved in strategic planning in European R&D, or play a role in fund raising for R&D programs.

- o ISTVS should rather choose a passive role in that ISTVS connections should be utilized by its members to acchieve optimum results in the acquisation process (e.g. joint proposals to EEC).

5 CONCLUSIONS

Based on the results of this brief workshop during part I and the discussion among authors and audience during part II the following main conclusions can be drawn:

- ISTVS as an organization is able to serve as a platform to communicate R&D information, needs and future directions among its members.

- There definitely appears to be a need for publishing comprehensive R&D overviews/literature through ISTVS to its member (but let us not forget that there already exists a SFM literature data base!); it appears that often research is started in some areas beginning at "square zero" and efforts are unnecessaryly repeated because existing valuable background information is not known to the researcher (or being ignored?)

- Because of the fact that industry and users were underrepresented in the group, our strive for closing the gap between researcher, manufacturer and user could not be continued, which - to a certain extent - seemed to hold true for the overall conference; the relation of presented results/discussions to practical application was missing too often. For the same reason our results and conclusions cannot be generalized.

<u>Table 1:</u> Which models are we talking about (numbers indicate the entries)

Type of model	Total entries	Areas of interest			
		Agriculture	Forestry	Transportation	General
Soil-running gear interaction					
o Wheels	22	9	2	10	1
o Tracks	4	-	-	2	2
Dynamics/ride comfort	12	5	1	6	-
Handling/steering safety	6	2	-	4	-
Plant growth/ compaction	3	3	-	-	-
Overall system modeling	7	2	-	4	1

Table 2: Types of models in use and areas of application

VEHICLE USER	DESIGNER, DEVELOPER, MANUFACTURER
o Analysis of experiments	o Traction prediction
o Traction performance prediction	o Prediction of dynamic behavior
o Tire selection	o Safety design
o Ride cabability prediction	o Performance prediction
o Mission performance prediction	o Concept evaluation
	o Mission oriented design

GENERAL DISCUSSION

Chairman: Brig. Gen. S.A.K. Areskoug

The concluding discussion mainly concerned the general questions of what ISTVS should aim at in the future.

It was significant that the three Workshop groups had very much the same wishes.

- The first was that the reviewed ISTVS standards, which have been ready for printing for some time, shall be issued as soon as possible. They should be printed in a separate booklet and should be marketed and spread widely outside ISTVS.

- There is a large number of existing standards, test procedured etc, that concern ISTVS field of interest. And much work is going on in different groups around the world. The knowledge and use of this are to a large extent very limited. ISTVS should try to compile and evaluate this matter and further its appropiate use.

- Much knowledge and many valuable research results are buried in older ISTVS proceedings and reports. They are largely unknown and seldom referred to by the researchers of today. ISTVS should strive at facilitating and stimulating the use of these funds.

It was briefly discussed how some working groups could be formed for further treating of these items.

On proposal of the President R.D. Wismer it was recommended that the ISTVS Board of Directors should take up the conclusions of the workshops for consideration.

The Chairman thanked the group leaders for their presentations and all the participants for their contributions and closed the session.

4th European ISTVS Conference
Closing Remarks by Vice President

In his closing remarks the Vice-President, Dr Dwyer, congratulated the organising committee on a very successful conference. He thanked all the authors and said that the written proceedings represented a valuable addition to the literature in this field and expressed the hope that they would acheive wider circulation than just among those people who had attended the conference.

He thanked IMAG and the Dutch Army for providing facilities for the field demonstrations and congratulated all those who had taken part on their energy and enthusiasm.

Dr Dwyer then went on to discuss the various formats which had been tried for the these types of conferences and expressed his personal preference for poster sessions rather than workshops. Posters provided the ideal stimulant to informal discussion, he said and, in the right environment and with adequate time available, could be a valuable addition to conferences of this type. Workshops, on the other hand, had not been as successful, in his experience, because they often lacked the necessary stimulation to trigger off a lively discussion. This he felt could be usefully considered when planning future conferences.

He also suggested that we should give further thought to improving our methods of communicating. Does all material lend itself to presentation by lecture? he asked, or should we make better use of demonstrations models, videos etc? Engines and Scientists are better at doing research than communicating their results to each other, let alone to others,he suggested and added that perhaps we should take lessons from the advertisers on how to communicate information quickly and efficiently for, after all, this is one of the main purposes of holding conferences.

Dr Dwyer ended by thanking the Conference Organising Committee again and also Brig. Gen. Stig Areskoug, Deputy General Secretary for Europe, not only for the advice and assistance which he had provided during preparations for this conference, but also for all the invaluable work he had done for ISTVS over so many years, particularly in Europe. Finally he thanked all the participants for their attendance, expressed the hope that he would see them again on similar, future occasions and wished them a safe journey home.

ISTVS

International
Society for
Terrain-
Vehicle
Systems

4th EUROPEAN CONFERENCE

Wageningen, The Netherlands

21-23rd March, 1989

TECHNICAL PROGRAMME

IMAG

MONDAY 20 March, 1989

18.00-20.00 Registration at IAC
19.30-21.00 Ice Breaker Party at IAC

TUESDAY 21 March, 1989

8.00- 9.00 Late registration at IAC

IAC Conference Centre: "kleine zaal"

9.00- 9.10 Conference Opening by:
- Brig Gen SAK Areskoug
  (Deputy General Secretary for Europe of ISTVS)
- Mr RD Wismer
  (President of ISTVS)
- Mr GJH Rijkenbarg
  (Interim Director of IMAG)

9.10- 9.30 Opening Address: Mr UD Perdok (Benelux Secretary ISTVS)
"Terrain-Vehicle Systems and Sustained Soil Quality"

9.30-10.00 General Report Sessions I and II
Dr FGJ Tijink (IMAG, Wageningen NL)

10.00-10.30 Coffee at the self-service restaurant of IAC

10.30-12.00 Plenary Sessions I and II.
Session I : "Field Traffic and Soil Quality for Plant Growth"
Session II: "Vehicle Systems and Soil Quality for Military Training Areas"
Chairman: prof H Kuipers
(Tillage Laboratory, Agric. Univ. Wageningen NL)
See page 4 for list of speakers

12.00-13.30 Lunch at the self-service restaurant of IAC

13.30-15.00 (continued) plenary Sessions I and II.
Chairman: prof H Kuipers
See page 4 for list of speakers

15.00-17.00 Workshops
There will be coffee and tea at the discussion rooms.

The self-service restaurant of IAC is open for dinner from 18.00-19.30.

WEDNESDAY 22nd MARCH, 1989 **WHOLE DAY EXCURSION**

SUMMARY PROGRAMME (time table)
(*See Excursion guide for detailed programme*)

7.45 **IAC Entrance**
Fit on boots*

8.00 **Depart by coaches** ** **from** IAC Entrance

8.15 **Arrive Site A**
Institute of Agricultural Engineering IMAG
Introduction by Mr UD Perdok
Exhibits and demonstations
Coffee

10.30 **Depart from IMAG**

11.30 **Arrive at Site B**
Military Training Areas "Stakenberger Heide" and "Elspeetse Heide"
Change into military vehicles for a trip to military training areas

12.30 **Depart by coaches**

13.00 **Arrive at Officers' Mess "De Wittenberg"**
Lunch
Explanation about Site C programme
by: Mr RE van Woudenberg (military vehicles)***
Mr PHAM Oome (civil vehicles)****

14.15 **Depart from "De Wittenberg"**

14.30 **Arrive at Site C**
"Stroese Zand"
Demonstration of terrain vehicles

17.00 **Depart by coaches from "Stroese Zand"**

18.00 **Arrive at Castle "Doorwerth"**
Conference dinner (*diner ambiant*)

22.00 **Depart by coach from Castle "Doorwerth"**

22.20 **Arrive at IAC.**

*	:	boots made available by Vredestein Tyres
**	:	coaches made available by DAF Trucks
***	:	military vehicles made available by the Dutch Army
****	:	civil vehicles made available by GINAF Trucks

THURSDAY 23rd March, 1989

IAC Conference Centre: "Kleine Zaal"

9.00- 9.30	General report Session III Mr EB Maclaurin (RARDE, Chertsey UK)
9.30-10.00	Plenary Session III "Advances in Mobility Devices and Soil-Vehicle Modelling" Chairman: Mr PD van der Koogh (TNO Road-Vehicles Reseach Institute, Delft NL) See page 4 for list of speakers
10.00-10.30	*Coffee at the self-service restaurant of IAC*
10.30-12.00	(continued) plenary session III Chairman: Mr PD van der Koogh
12.00-13.00	Lunch at the self-service restaurant of IAC
13.00-14.00	Round off the workshops
14.15-15.15	Presentation of the conclusions from the workshops General discussion Chairman: Brig Gen SAK Areskoug
15.15	Conference closing

After the closing session there will be coffee and tea in the IAC restaurant.

ORDER OF PRESENTATION

Tuesday, 21st March

(Sessions I and II)

10.30 Hadas, Shmulevich and Wolf
10.40 Sitkei
10.50 Wästerlund
11.00 Parringer
11.10 Lerink
11.20 Grahn
11.30 Schwanghart
11.40 Neukam
11.50 Van den Akker and Carsjens

13.30 Sever
13.40 Grecenko
13.50 Dwyer and Stadie
14.00 Vermeulen and Arts
14.10 Zwart
14.20 Beije
14.30 Gyldberg

Thursday, 23rd March

(Session III)

9.30 El Razaz and Crolla
9.40 Armbruster and Kutzbach
9.50 Heine and Kutzbach

10.30 Crolla and Maclaurin
10.40 Bolling
10.50 Ronai
11.00 Meijer, Siefkes and Göhlich
11.10 Heiming
11.20 Laib
11.30 Melzer
11.40 Hohl

ISTVS

International
Society for
Terrain-
Vehicle
Systems

4th EUROPEAN CONFERENCE

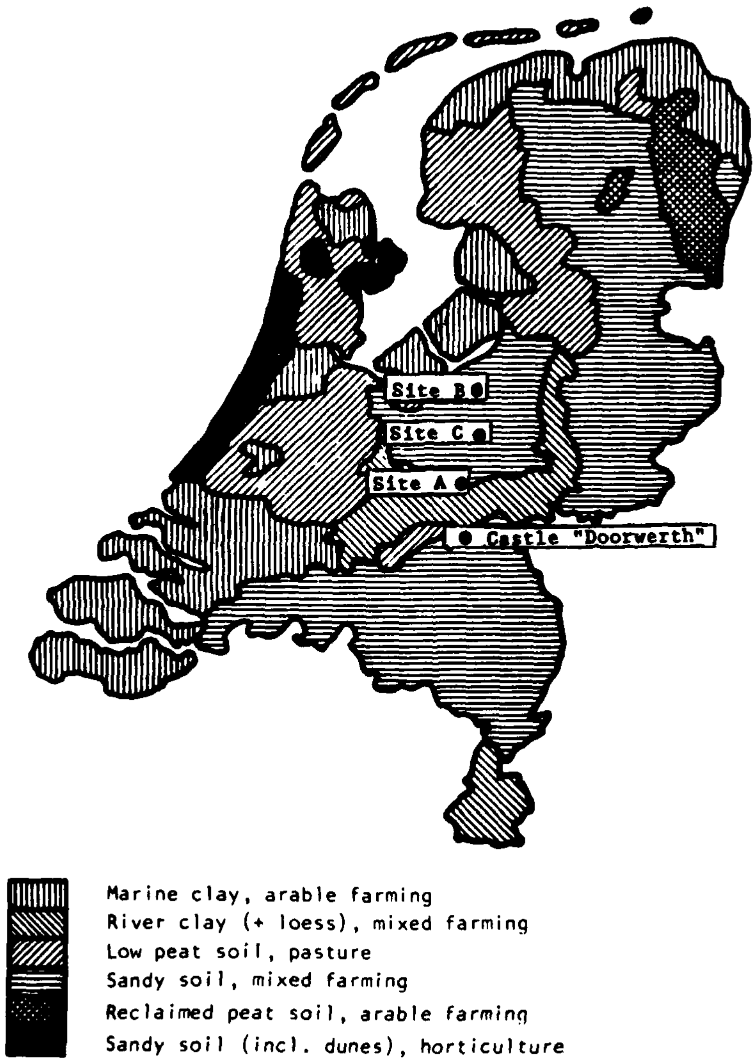
Wageningen, The Netherlands

Wednesday 22nd March, 1989

EXCURSION GUIDE

Participants are reminded to watch the time and be prompt in assembling at the specified times for coach departures so that the excursion can keep to the timetable.

IMAG



map of the Netherlands

SUMMARY PROGRAMME

Time	Short description	Page No. for details
7.45	**IAC Entrance** Fit on boots*	
8.00	**Depart by coaches** ** **from IAC Entrance**	
8.15	**Arrive Site A** **Institute of Agricultural Engineering IMAG** Introduction by Mr UD Perdok Exhibits and demonstations Coffee	77
10.30	**Depart from IMAG**	
11.30	**Arrive at Site B** **Military Training Areas "Stakenberger Heide" and "Elspeetse Heide"** Change into military vehicles for a trip to military training areas	96
12.30	**Depart by coaches**	
13.00	**Arrive at Officers' Mess "De Wittenberg"** Lunch Explanation about Site C programme by: Mr RE van Woudenberg (military vehicles)*** Mr PHAM Oome (civil vehicles)****	
14.15	**Depart from "De Wittenberg"**	
14.30	**Arrive at Site C** **"Stroese Zand"** Demonstration of terrain vehicles	98
17.00	**Depart by coaches from "Stroese Zand"**	
18.00	**Arrive at Castle "Doorwerth"** Conference dinner (*diner ambiant*)	
22.00	**Depart by coach from Castle "Doorwerth"**	
22.20	**Arrive at IAC.**	

* : boots made available by **Vredestein Tyres**
** : coaches made available by **DAF Trucks**
*** : military vehicles made available by the **Dutch Army**
**** : civil vehicles made available by **GINAF Trucks**

Site A Institute of Agricultural Engineering IMAG Wageningen

Page No.

A.1 Low Ground Pressure Farming System.

Purpose:

A Farming System where the average ground pressure in the contact area of wheels and soil is maintained at a constant low level during field operations is laid out to prevent excessive compaction in the arable layer as well as in the subsoil. Such a system (LGP) based on a 60 ha. arable farm under Dutch conditions, is presently being compared with a normal practice (HGP) and a Zero traffic (Z) system. Performance a.o. in terms of yield and product quality are being evaluated to assess the perspective of such a system.

Brief system description:

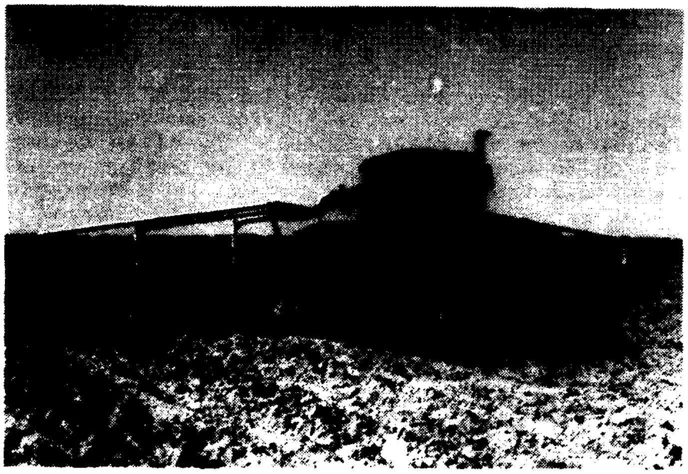
In the LGP system, essentially the same tractors and tools are used as with the normal practice system, but with wider tyres, that allow application of lower inflation pressures. Tyres are selected for operation in the deflected range. Under this condition, the average ground pressure is approximated by the expression (1.25 * inflation pressure). Average Ground Pressure and corresponding tyre inflation pressures used in the experiment are mentioned in the tabel.

	HGP		LGP	
	Pc*	Pi**	Pc	Pi
Uncontrolled traffic before sowing/planting	100	80	50	40
other operations (tractors, combine)	200	160	100	80
trailer- and implement tyres	300	240	100	80

* average ground pressure (kPa)
** tyre inflation pressure (kPa)

The experiment:

The three systems are being compared since 1985 on the IMAG experimental farm "Oostwaardhoeve" at Slootdorp on a practical scale. The experiment further comprises a crop rotation of ware potatoes, onions, winterwheat and sugar-beets, four replications, and a comparison of shallow subsoiled and non subsoiled field.



Spreading fertilizer in spring with wide tyres.

Measurements:

*field scale:applied loads, rut patterns, traffic frequency
*soil :dry bulk density, volumetric soil, water and air fractions at pF2, dry bulk density, cone-index, structure (morphology), rut depths and absolute surface height in time, seed bed quality, specific ploughing resistance, uniaxial compression behaviour (state-diagrams), soil water matrix potential, temperatures and water contents in time.
*crop :germination, plant-density, degree of soil cover by leaves, rooting patterns, yield, grading and quality.

Cooperation:

*National : LUW, Staring Centre, IB, PAGV.
*International: AFRC Engineering, Silsoe, Great Britain.
FAL, Braunschweig, West germany.

Further information:

IMAG,
Ir. G.D. Vermeulen
P.O. Box 43,
6700 AA Wageningen.
08370-94241.

A.2 Telemetric measuring system for power requirement.

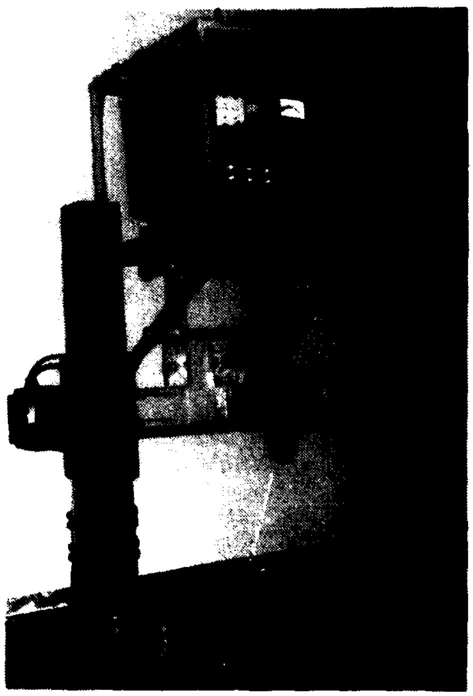
Purpose:

Measurement of the forces in the three-point hitch and rotational speed and torque of the p.t.o. are needed for our research on the power/energy requirement of tillage tools. To allow measurement of these forces under actual field conditions with a variety of tractor-implement combinations, the system is telemetric and consists of measuring elements that can be easily mounted on any tractor with a standard category II three point hitch.
Presently, the system is used to collect data on the power/energy requirement of a tillage tool at different soil compaction levels.

Main system parts:

Tractor:
*strain gaged measuring frame for lower line horizontal (left, right) and vertical (left, right) forces.
*strain gaged, top link extension for horizontal top link force.
*transducer for p.t.o. torque and rotational speed.
*signal transmitter (6-channel, transmission distance 2 km).

Mobile van:
*signal receiver/demodulator.
*datalogger (sampling time 0,01 sec. per recorded value).
*HP 9000 computer with software to enable direct output of results.



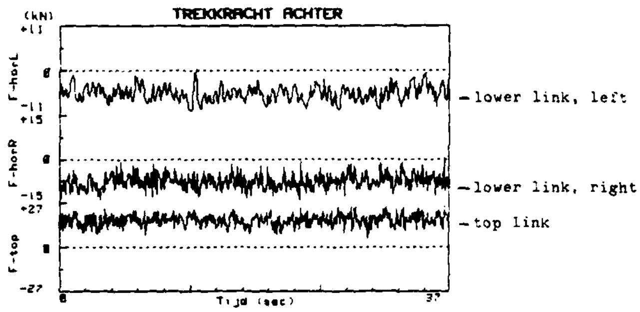
Tractor mounted parts of the measuring system.

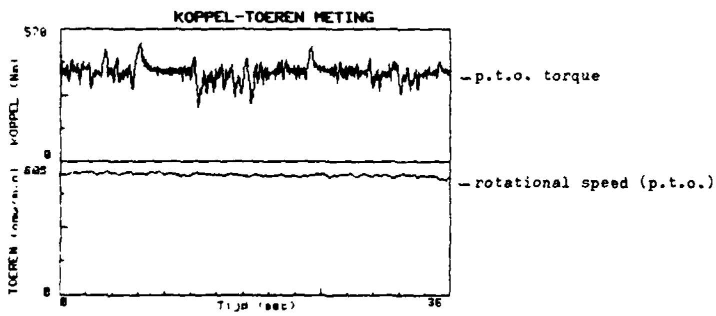
Presentation:

Metingnummer : 1 Meettijd : 37.10 Sec

<ACHTER>		GEM.SPAN.	MIN.WAARDE	MAX.WAARDE	GEM.WAARDE	TOTAAL
Hor. links	:	-5.925 V	-10.18 kN	.53 kN	-5.925 kN	===========
Hor. rechts	:	-4.010 V	-14.54 kN	.28 kN	-8.020 kN	2.913963 kN
Topstang	:	4.2148 V	6 kN	25.56 kN	16.859 kN	===========

		GEM.SPAN.	MIN.WAARDE	MAX.WAARDE	GEM.WAARDE
Koppel	:	7.7590 V	237 Nm	518.5 Nm	387.95 Nm
Toerental	:	7.7415 V	519.4 o/m	557.2 o/m	541.91 o/m
Vermogen	:	---->	---->	---->	22.015 kW





Output of telemetric measuring system.

Further information:

IMAG,
Ir. G.D. Vermeulen
P.O. Box 43,
6700 AA Wageningen.
08370-94241.

A.3 Pressure Cells.

Purpose:

Due to increasing wheel loads in agriculture in the last 10 - 15 years, subsoil compaction becomes a problem ever more. In contrast with the topsoil the subsoil can be loosened with great effort only. To study subsoil compaction induced by vehicle traffic pressure cells are used frequently to measure stresses in the topsoil-subsoil interface.
In many cases the results are questionable. First the soil has to be disturbed to implant the pressure cells and they are mostly stiffer than the soil, so stresses are concentrated on the cells. Soil bin experiments have shown that stresses can be measured accurately if the cell is embedded in the hard subsoil with the surface in plane with the topsoil-subsoil interface.
We tested the reliability of pressure cells in field experiments with two installation methods.
In the first method the topsoil was removed over a large width. In this way the pressure cells can be installed with great care and a homogeneous topsoil condition can be created. This method is suitable for comparative experiments, for instance to measure the influence of tire size, inflation pressure or wheel load.
In the second method the cells were installed by way of horizontal milled holes to prevent topsoil disturbance. This method is suitable to measure soil pressures with real soil conditions, for instance to measure the effect of moisture content on stress distribution.
The pressure cells used have a diameter of 7.6 cm and a height of 1.7 cm. Deflection of the sensitive cell surface is measured with strain-gauges. The reproducability of the measurements with the first method is better than with the second method. Both methods are satisfactory.
The reliability of the experiments with pressure cells can be tested by comparing the reaction force computed from the vertical stress distribution with the exerted wheel load. In the tests the mean reaction force is approximately 9% too low, but this difference is acceptable in this kind of measurements.
More detailed information about the tests and results can be found in the Conference Proceedings, Vol 1, pp 1-7.

Further information:

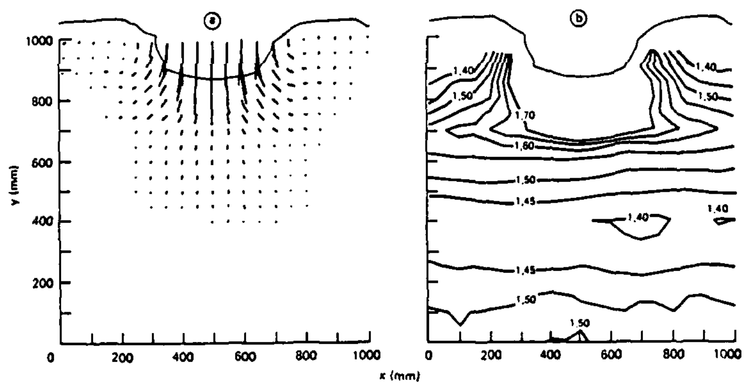
The Winand Staring Centre for Intergrated Land,
Soil and Water Research,
Ir. J.J.H. van den Akker,
P.O. Box 125,
6700 AC Wageningen.
08370 - 19100

Tillage Laboratory of the Wageningen Agricultural
University ,
Dr. Ir. A.J. Koolen,
Diedenweg 20,
6703 GW Wageningen.
08370 - 83451.

A.4 Photographed Point Grid.

Purpose:

Due to heavy wheel loads the subsoil increasingly compacts. Measurements of subsoil compaction with generally applied undisturbed volume sampling techniques is not sensitive enough. This together with the need to know which deformations occur during compaction, is why we have developed a new sensitive method to measure and visualize compaction and deformation in the subsoil. A vertical point grid positioned into the soil profile perpendicular to the driving direction is photographed before and after wheel passage. Through monoplotting, a photogrammetric technique, the position of the grid points can be measured and their displacements calculated. Volume changes due to compaction are found by computing the volumes between four grid points before and after wheel passage. Changes in dry-bulk density as low as 1% can be measured.



Displacements of grid points by wheel passage (A) and iso-density lines (g.cm-3) after wheel passage (b).

Further information:

The Winand Staring Centre for Integrated Land,
Soil and Water Research,
Ir. J.J.H. van den Akker,
P.O. Box 125,
6700 AC Wageningen.
08370 - 19100

A.5 IMAG Single Wheel Tester.

Purpose:

*determination of the performance of agricultural tyres under field conditions.
*research on soil compaction under single tyres.
*research on soil pressure-deformation relationships, using the wheeltester equipment for in situ plate sinkage measurements (BeVa meter).

Technical description:

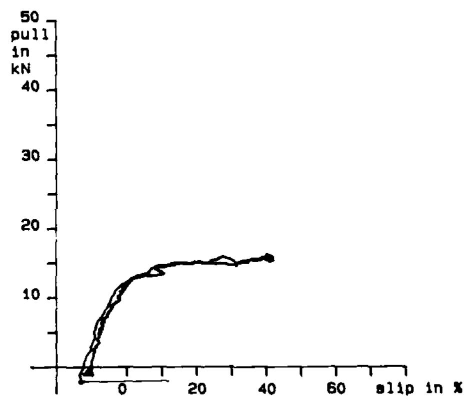
The IMAG tester consists of an articulated steered framework with the rear axle driven. In the middle of the front part test wheels of 1.2 to 2 meter diameter and a width up to 1 meter can be easily mounted. The total weight of the tester is 100 kN and the load on the test wheel can be maximum 42 kN (weight transfer). The forward speed is maximum 30 km/h on the road and maximum measuring speed is 10 km/h. The wheel slip has a range between 0 and 60%. Facilities for measuring wheel load, pull, rolling resistance, torque, forward speed and angular speed of the test wheel as well as track depth are built in.
Data storage is done by a Compaq portable II computer (640 RAM and 20 Megabyte harddisk). The programme for data collection (with the help of a Dash-16 card) and the possibility to give a direct presentation on paper in the field is made in Turbo Basic. Asystant+ is used for further analysis of the collected data.

IMAG Single Wheel Tester.

Presentation:

```
Name datafile-------------:89003
Date----------------------:01-25-1989
Time----------------------:14:41:01
Location and Plot---------:Oostwaardhoeve, A17, sandy
Soil condition------------:Arable normal; moist, settled
Weather condition---------:clouded, dry
Tyre size and Tyre type--:18.4R38 8PR
Tyre section width--------:0.474
Static loaded radius in m:0.755
Tyre pressure in kPa------:80
Tyre loaded in N----------:27000
Resolution----------------:10
```

Diagram : Pull - slip



IMAG

Direct output of a Pull - Slip curve.

Further information:

IMAG,
Ing. W.B.M. Arts
P.O. Box 43,
6700 AA Wageningen.
08370-94243.

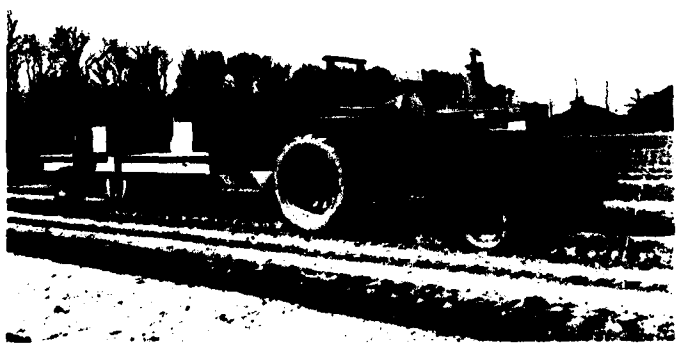
A.6 Loading frame.

Purpose:

*Simulation of a variety of existing and future loading techniques, for wheel-soil-plant research with the possibility to vary the technical variables independently.
*Preparation of soil strips for single-wheel-tester work and studies of soil behaviour under load.

Technical description:

The loading frame consist of a framework for applying 45 - 165 kN load to an exchangeable running gear of up to 2.0 meter wide and 2.0 meter in diameter on one axle in the centre of the frame.
In addition to its own weight of 45 kN, 120 kN can be placed on the frame by means of concrete blocks of 5000 N each.
The loading frame is towed by a wide span (3 meter) tractor that leaves the zone to be loaded und' turbed. A force transducer is mounted between tractor and loa..ing frame to measure rolling resistance of the running gear.
The running gear currently available consists of 4 non-driven steel roller elements, each 0.5 meter wide and 1.2 meter in diameter. The elements can be mounted on the axle in various configurations.
Future extensions may include elements to vary contact length, slip and vibratory energy.



Loading frame with lined-up rollers pulled by a tractor with a track width of 3.00 m.

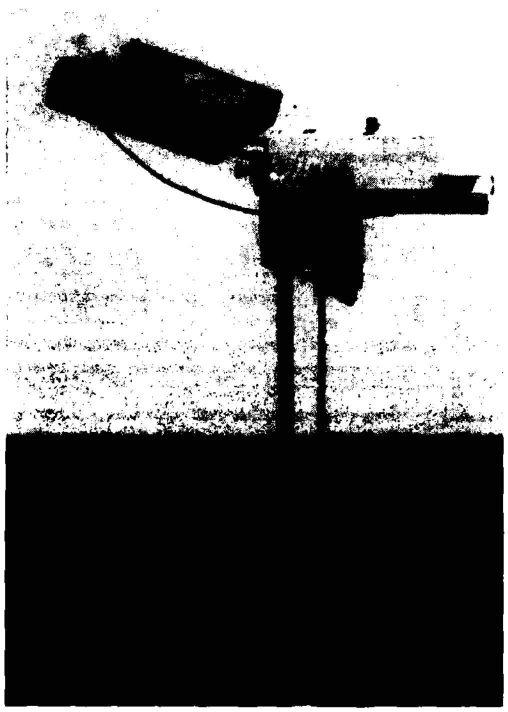
Further information:

IMAG,
Ing. W.B.M. Arts,
P.O. Box 43,
6700 AA Wageningen.
08370-94243.

3.7 Penetrometer.

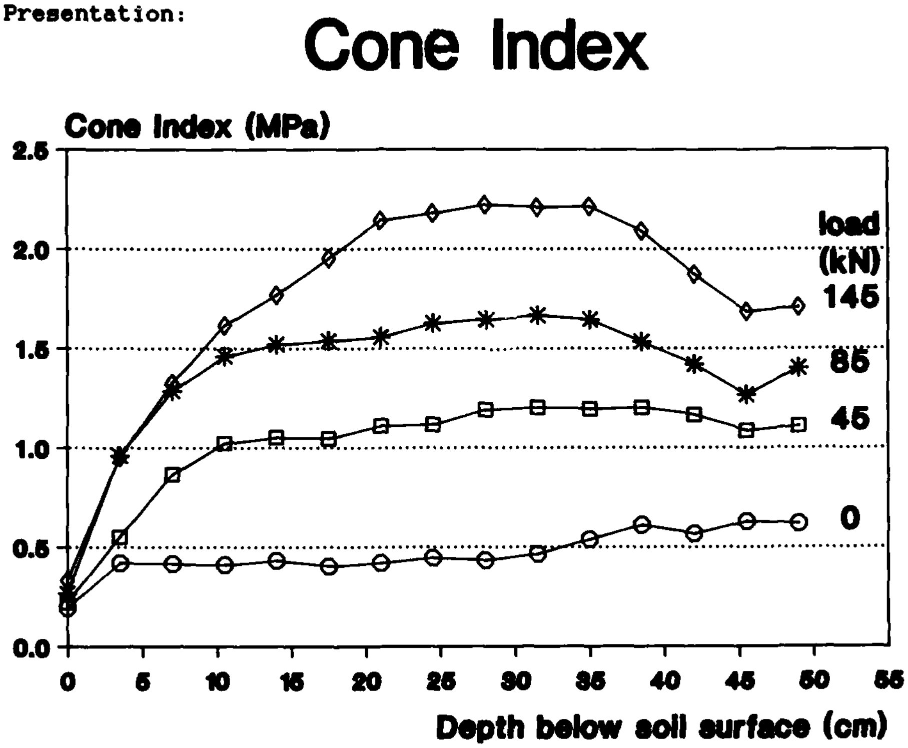
Technical discription:

The Bush recording penetrometer measures up to depths of 55 or 70 cm at intervals of 3.5 and 5 cm respectivily.
The used 30 degrees circular cones are in conformity with ASAE standard S 313.1. Type A has a cone base of 3.2 cm^2 and type B 1.3 cm^2. Data storage is done by an Epson HX-20 portable computer. A small printer allows direct output of data in the field. A program for automatic standard output and storage on tape was developed. After transferring the data to a Reflex database on a personal computer more appropriate presentations can be produced.



Bush recording penetrometer with Epson HX-20 computer.

Presentation:



Output of cone resistance with the database programme Reflex.

Further information:

IMAG,
Ing. W.B.M. Arts,
P.O. Box 43,
6700 AA Wageningen.
08370-94243.

3.8 Laser equipment.

Purpose:

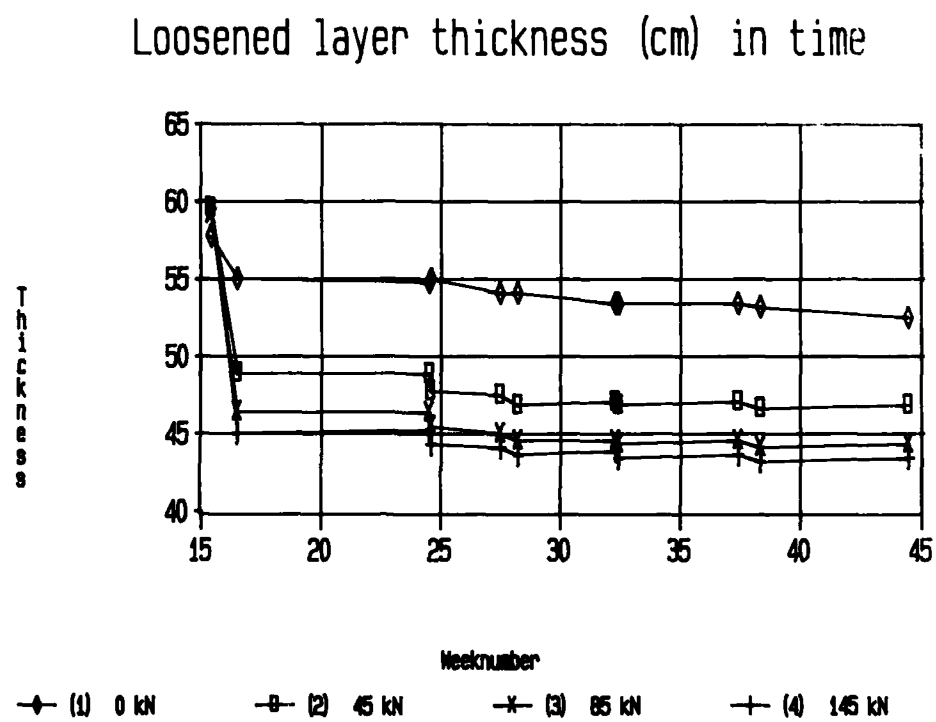
Measurement of changes in the absolute height of different layers in the soil profile in time.
In our research with the loading frame we measure the thickness of the tilled layer. On the interface between tilled layer and subsoil we installed concrete plates of 30 * 30 cm for that purpose. The position of these plates as well as the position of the soil surface is measured with the laser equipment. For measurement of absolute position, a reference point of fixed absolute position is also measured once for each measuring session.

Technical description:

The equipment (Laser alignment) consits of the electronic laser transmitter that creates a horizontal laser level and a receiver that can be moved by hand on a measuring staff with mm scale. Maximum reach is 300 meter. The accuracy of the transmitter on 100 meter distance is 1.5 mm. The accuracy of the receiver is 0.8 mm.
The transmitter as well the receiver are equipment with battery power supply. The total system is waterproof what makes it very handy for use in the field
After transferring data to the database programme Reflex or the graphics programme Harvard Graphics (both installed on an IBM compatible PC) output is produced.

Laser equipment.

Presentation:



Output of thickness of loosened layer with the database programme Reflex.

Further information:

IMAG,
Ing. W.B.M. Arts,
P.O. Box 43,
6700 AA Wageningen.
08370-94243.

3.9 Agricultural Tyre Advisor.

In november 1988, we started this project. Publications on agricultural tyres are hardly used in practice. So we looked for a way to make this knowledge available in a more accessable form. We also wanted to compare the suitability of Turbo Prolog for building a prototype knowledge based system, with other expert system shells.

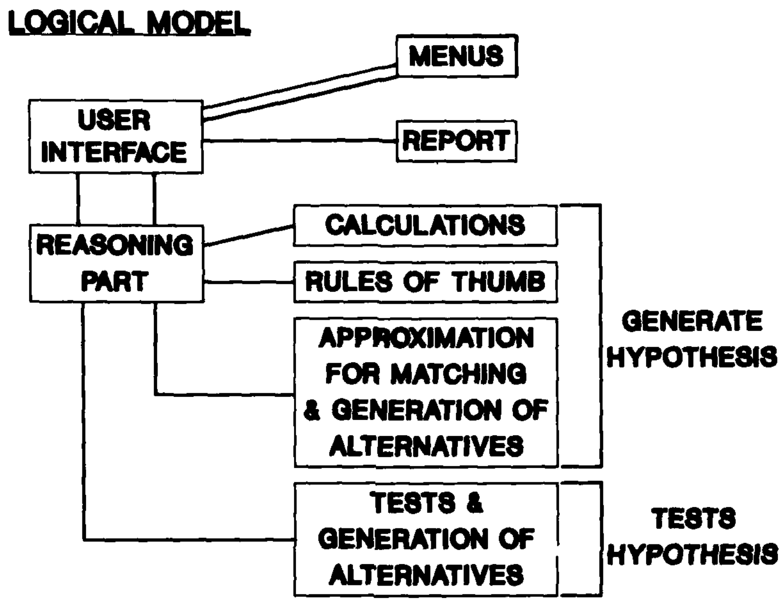
The first aim required that the system should be cheap (in terms of available hardware and licensing costs) and that arithmatic functions are available, the second that uncertainty is not a major aspects of knowledge. These requirements proved complementary.

We now demonstrate the first prototype. We reached this fase sooner than expected. The system is able to (interactively) suggest tyres, choosen from an available set, suitable for a given set of uses. It also takes into account the effect of soil type on subsoil compaction. Furthermore the user can specify special constraints on tyre width and pressure.

Knowledge based systems, colloquially called expert systems, differ from conventional software by their explicit representation of facts and heuristics of the domain. We represented the knowledge, where possible, in a declarative way. This way it is not necessary to keep track of all possible interactions between already excisting, and newly added knowledge. Logic programming is specially suitable for representing declarative knowledge, like facts and constraints.

Functionally, knowledge based systems should reason with a large amount of knowledge, be able to handle conflicting requirements and uncertainty, explain and justify their actions, and learn from experience. We know of no system that fulfils all these requirements.

In our system we can deal with a moderate amount of knowledge, handle conflicting requirements, while explanation of dicisions where a human expert would so as well, is next to be implemented. In the present form the system generates an hypothesis, based on information of the user heuristics and calculations, about the best tyre to be used. It selects from the available tyres in the database the tyres that match the description best, and then test wether the available tyres confirm to all constraints. As the system shows the advice, the user may suggest or modify the conditions taken into account.



Further information:

*Agricultural University Wageningen,
K. de Bruyn
Drs. L. Maris (Department of Computer Science),
Dreyenplein 2,
6703 BC Wageningen.
08370-84725

*Agricultural University Wageningen,
Dr. Ir. W. Huisman (Department of Agricultural Engineering and Physics),
Mansholtlaan 12,
6708 PA Wageningen.
08370-62169

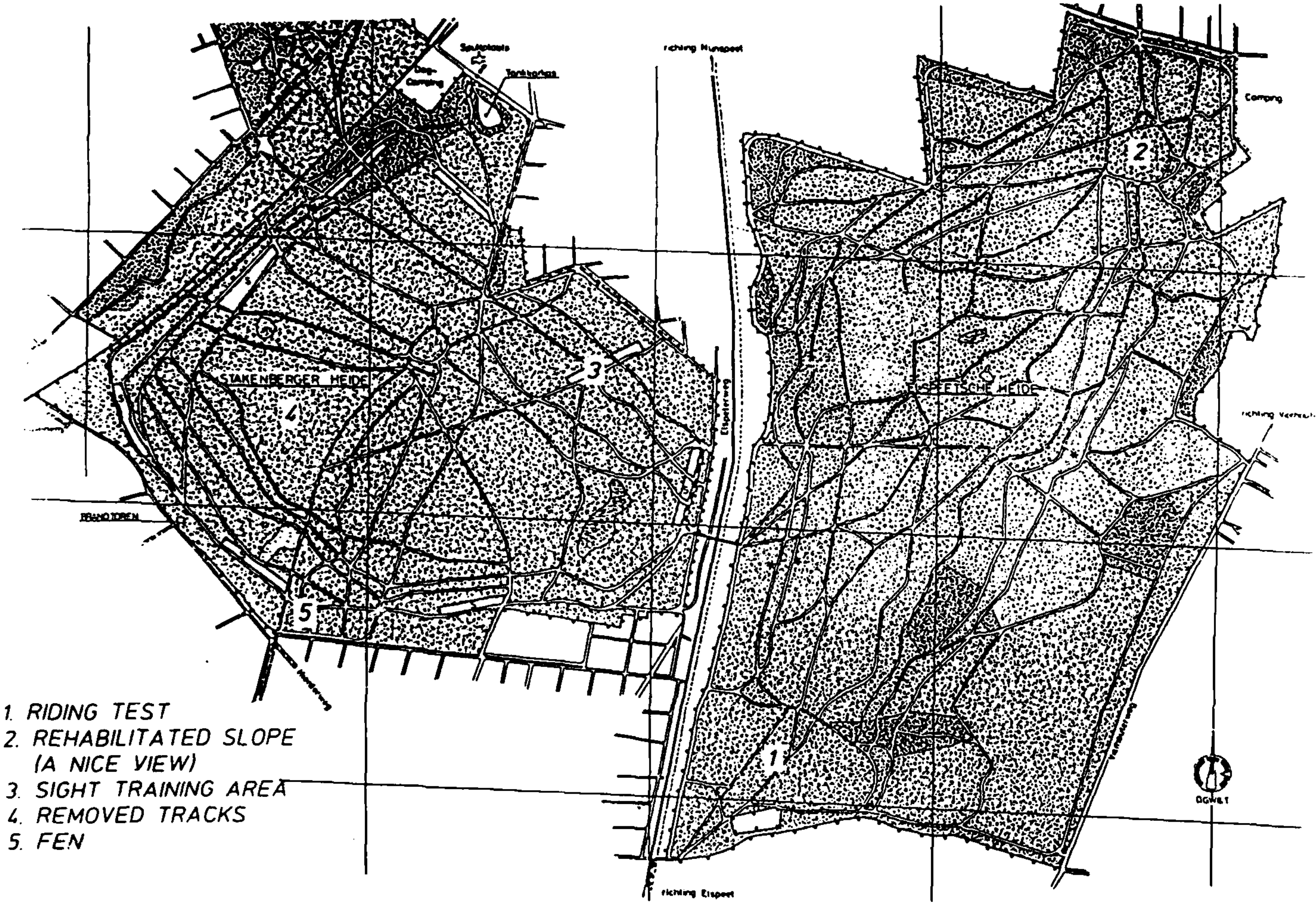
*IMAG,
Ing. W.B.M. Arts,
P.O. Box 43,
6700 AA Wageningen.
08370-94243.

SITE B MILITARY TRAINING AREAS "STAKENBERGER HEIDE" AND "ELSPEETSE HEIDE"

The Elspeetse Heide and the Stakenberger Heide are heathland areas, used for military training activities as well as for outdoor recreation and nature conservation purposes. Heathlands in the Netherlands originate from woodland areas, which disappeared by agricultural exploitation thousand years ago. The landscape and vegetation is being maintained now by cutting trees, mowing, burning and by removing the topsoil regularly.
Natural fens occur on places with impermeable layers in the sand.
The areas are owned by the Municipality, who also carries out the management. Road management however is in the hands of the military authorities. Nowadays wheeled and tracked vehicles are permitted only to go on roads. Special places have been marked for sight training with guns.
In 1978 the road system has been adapted to new training conditions. The unpaved roads have deeply been digged; three or four roads run parallel. In the same time abandoned roads have been restored. Before, in 1964, vast denuded areas on the Stakenberger Heide had been restored already, freely used by vehicles in the late fifties and early sixties.

During the trip we can see:

1. effects of off-road locomotion in well controlled experiments, carried out in 1982. On this soil no effects are visible.
2. results of restorating denuded areas, 6 years old.
   The results strongly depend on soil type and slope.
   Note also the new road systems.
   Here we wil stop for a nice view.
3. Sight training area, used since 1978.
4. Results of the same restoration techniques, 10 as well as 24 years old. Heath vegetation recovers especially on very poor soils (removed tracks).
5. Original fen.


richting Nunspeet
Camping
STAKENBERGER HEIDE
richting Elspeet
1. RIDING TEST
2. REHABILITATED SLOPE
(A NICE VIEW)
3. SIGHT TRAINING AREA
4. REMOVED TRACKS
5. FEN

SITE C	"STROESE ZAND"

Five topics will be demonstrated on this beautiful military training area:

1. Circuit (run 1-10)
2. Vegetation effects of vehicles (run 11-13)
3. Drive on a graded surface (run 14-16)
4. Hill climbing (run 17-22)
5. Short inspection of the vehicles (at the end of the demonstration)

Run No.	Vehicle	Short description of actions	
1	LARO (photo 1)	Normal drive, stop, drive off The same at	4x2 4x4
2	YA 4440 (empty) (photo 2)	Normal drive, stop, drive off The same at	4x2 4x4
3	YA 4442 (empty) (photo 3)	Normal drive, stop, drive off The same at	4x2 4x4
4	YA 4442 (loaded) (photo 3)	Normal drive, stop, drive off The same at	4x2 4x4
5	YAZ 2300 (photo 4)	Normal drive, stop, drive off	
6	YHZ 2300 (photo 5)	Normal drive, stop, drive off	
7	GINAF Fire Truck (photo 7)	Normal drive, stop, run off	
8	GINAF Slurry Tanker (photo 8)	Normal drive, stop, run off	
9	GINAF 10x8 (photo 9)	Various actions	
10	YPR (photo 6)	Normal drive, stop, fast drive off, bend, 180^{o} turn	
11	YAZ 2300 (photo 4)	Curve driving in relation to vegetation	
12	GINAF Slurry Tanker (photo 8)	Curve driving in relation to vegetation	
13	YPR (photo 6)	Curve driving in relation to vegetation	

CHANGE OF LOCATION

DRIVE ON GRADED SURFACE

14	YA 4440 and YA 4442	Both driving at the same time on a graded surface
15	YHZ 2300 and GINAF Slurry Tanker	Drive at low tyre inflation pressure over a graded surface
16	YPR	drive on a graded surface

HILL CLIMBING

17 LARO

18 YA 4440 and YA 4442

19 YAZ 2300 and YHZ 2300

20 GINAF Slurry Tanker

21 GINAF Fire Truck

22 YPR

POSITIONING OF VEHICLES FOR SHORT INSPECTION

Photo 1.

Army Truck. General service
LAND ROVER, 4x4, 5 kN
Diesel engine 38 kW
Tyres 7.00 x 16

Photo 2.

Army Truck, flat load-bed
DAF, 4x4, YA-4440, 40 kN
Diesel engine 108 kW
Weight (empty) 68 kN
Tyres 12.00 x 20

Photo 3.

Army Truck, flat load-bed
DAF, 4x4, YA-4442, 40 kN
Diesel engine 133 kW
Weight (empty) 76 kN
Tyres 13 R 22.5

Photo 4.

Army Truck, open loading platform
DAF, 6x6, YAZ-2300, 100 kN
Crane HIAB 90 kNm
Diesel engine 180 kW
Weight (empty) 128 kN
Tyres 13 R 22.5

Photo 5.

Army Truck, artillery tractor
for M114/39
DAF, 6x6, YHZ-2300
Diesel engine 180 kW
Weight 232 kN
Tyres 14.75 R 20

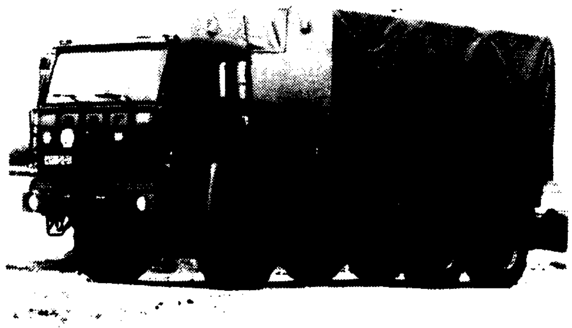


Photo 6.

Infantry armoured vehicle
YPR-765
Detroit diesel engine
Weight 120 kN

Photo 7.

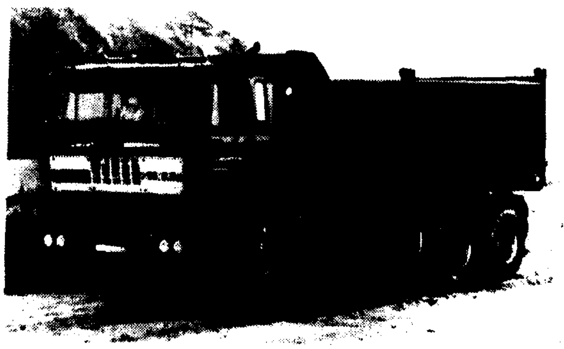
GINAF F 380 DKX
Fire Truck
6x6; max. G.V.W. 36 ton
Diesel engine 260 kW
Tyres: 16.5 R 22.5 (front)
       13 R 22.5 (rear)

Photo 8.

GINAF F 250 DU
Slurry tanker
6x6 (2 steering axles)
max. G.V.W. 25 ton
Tyres: 24 R 20.5

Photo 9.

GINAF F 521 DKZ
Tripper truck
10x8; max. G.V.W. 51.5 ton
Diesel engine 274 kW
Tyres: 16.5R22.5 (steering axles)
       13 R22.5 (rigid axles)



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